APPENDIX D

Evaluating Existing Water Resources Information in the Sierra Nevada Network for the Vital Signs Water Quality Monitoring Plan

September 2005

Andi Heard and John D. Stednick
Colorado State University

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Sierra Nevada Network (SIEN) of the U. S. National Park Service's Inventory and Monitoring Program is developing a Vital Signs monitoring plan. Water quality monitoring is one component of the plan. The initial steps in developing a comprehensive water quality monitoring plan include identifying, summarizing and evaluating existing water resources (National Park Service-Water Resources Division 2003).

The Sierra Nevada Network parks include Devils Postpile National Monument and Sequoia, Kings Canyon and Yosemite National Parks (Figure 1). Network parks are located on the western slope of the Pacific Crest in the Sierra Nevada Mountains and span seven major watersheds. These watersheds, from north to south, are the Tuolumne, Merced, San Joaquin, Kings, Kaweah, Tule and Kern. Runoff from these watersheds drains into the San Francisco Bay/ Sacramento–San Joaquin Delta in the north and the Tulare Lake Basin in the south. The Sierra Nevada parks protect a diversity of water resources, including over 4,500 lakes and ponds, thousands of kilometers of rivers and streams, seeps, wet meadows, waterfalls, hot springs, mineral springs and karst springs.

Water dynamics in the Sierra Nevada are a critical component of both the parks' ecosystems and the larger California water infrastructure. The region has a Mediterranean climate characterized by cool, wet winters and hot, dry summers. Most of the precipitation falls as snow in the mid and high elevations. The snowpack acts as a temporary reservoir, storing water that will be released during the warmer and drier months. Peak runoff typically occurs in May or June (Figure 2). Water is captured and stored for summer use in a series of reservoirs that line the Sierra foothills.

Water is the most valuable resource commodity in the Sierra Nevada. Sierra Nevada ecosystems produce approximately 2.2 billion dollars worth of ecosystem based revenues annually and water accounts for more than 60% of these revenues (SNEP 1996). Primary uses include irrigated agriculture, domestic water supplies, hydroelectric power, recreation and tourism. Water resources and associated aquatic and riparian habitats also have high ecological value. Approximately 21% of the vertebrates and 17% of plants in the Sierra Nevada are associated with riparian habitats (SNEP 1996).

Figure 1: Sierra Nevada Network parks and watersheds.

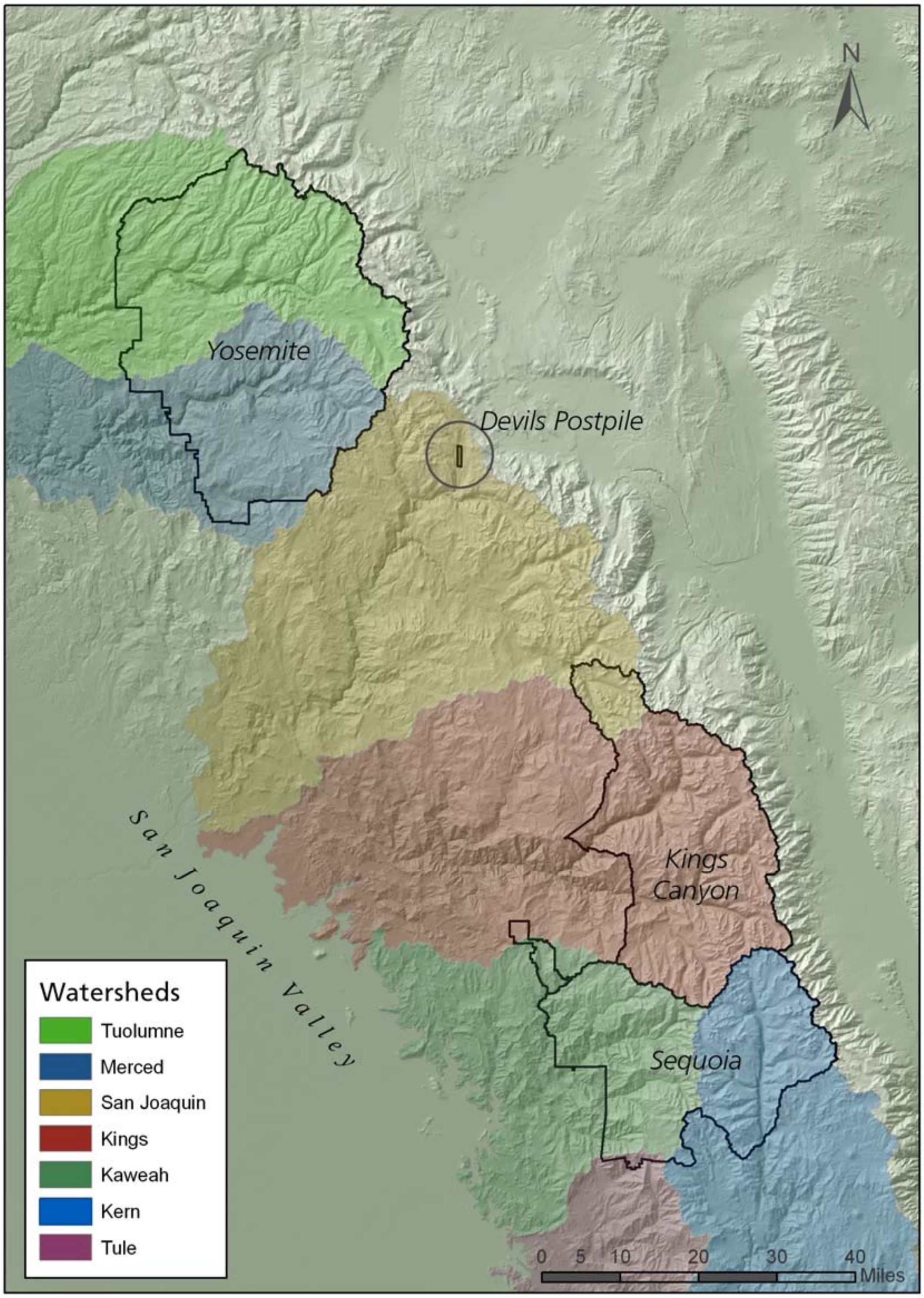
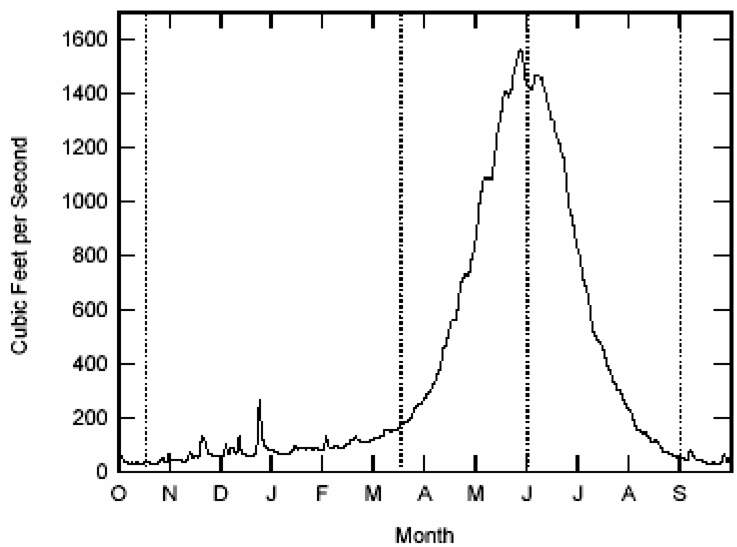


Figure 2: Representative mean annual hydrograph from the Merced River at Happy Isles in Yosemite National Park. National Park Service- Water Resources Division plotted the hydrograph using a 72 year record (National Park Service 1998). Vertical lines divide the hydrograph into four seasons.



PURPOSE AND SCOPE

The purpose of this report is to evaluate existing water quality information, including data sets, publications and current research and monitoring projects, for water resources in the Sierra Nevada Network parks. The network is developing a vital signs water quality monitoring plan using a three phase approach (Fancy and Gross 2004). Phase I entails synthesizing existing information, identifying key management issues, and developing conceptual models to support planning efforts. Phase II entails prioritizing vital signs indicators. Phase III is developing the monitoring design.

This report provides background information needed to develop a long-term monitoring plan. There are six objectives:

1. Describe the water resources in the parks.

2. Identify historic water resources research and monitoring projects. Document existing data sets.

3. Identify current water resources research and monitoring projects.

4. Identify local water resource issues including 303(d) waters, Wild and Scenic Rivers, and issues identified in 305(b) reports and by local managers.

5. Identify current and emerging threats to aquatic ecosystems.

6. Identify long-term data sets and analyze for temporal trends.

Current and Emerging Aquatic Ecosystem Threats

The State Water Resources Control Board and nine Regional Water Quality Control Boards, under the Porter-Cologne Water Quality Control Act, are responsible for the protection and enhancement of California's water resources. Each Regional Water Quality Control Board adopts Basin Plans, which contain beneficial use designations, water quality objectives and implementation programs. Sierra Nevada network parks fall under the jurisdiction of the Central Valley Regional Water Quality Control Board and have waters contained in both the Sacramento-San Joaquin and Tulare Lake Basins. Under sections 305(b) and 303(d) of the Clean Water Act, California is required to assess the overall health of the state's waters and identify waters that are not attaining water quality standards. The State must compile water quality limited waters in a 303(d) list and initiate the process to bring listed waters back into compliance. The Sierra Nevada Network parks do not contain any 303(d) listed waters (State Water Resources Control Board 2002). The State also has the authority to designate waters as Outstanding Natural Resource Waters. This designation is the highest level of protection that may be afforded to a water body. The Sierra Nevada Network parks do not have any Outstanding Natural Resource Waters; however, national park waters are strong candidates for this designation

The Sierra Nevada Ecosystem Project (SNEP) concluded that aquatic and riparian systems are the most altered and disturbed habitats in the Sierra Nevada (SNEP 1996). The primary reasons for the deterioration are changes in flow regimes, disturbances from land use practices, and the introduction of non-native organisms. Despite the impacts on aquatic and riparian habitats, basic hydrologic processes and water quality remain in relatively good condition (Kattelmann 1996). Hydrologic modifications and degraded water quality are of greatest concern in foothill reservoirs and downstream areas in the Central Valley.

The Sierra Nevada national parks protect many lakes, streams and rivers with unaltered flow regimes and good to high water quality. However, the parks water resources are subjected to natural and anthropogenic disturbances that have the potential to modify the systems and degrade water resources. Some of these stressors are localized, threatening relatively small areas or specific water bodies, and may include visitor use impacts, small dams and diversions, or mines. Local stressors, which vary between parks, are discussed in the individual park sections of this report. Water resources in the Sierra Nevada Network parks are also affected by systemic stressors, which occur at regional and ecosystem scales. Managers and researchers, using the findings from the Sierra Nevada Ecosystem Project (SNEP 1996), identified five important systemic stressors to Sierra Nevada systems: 1) loss of pre-Euroamerican fire regimes, 2) non-native invasive species, 3) air pollution, 4) habitat fragmentation, and 5) rapid anthropogenic climatic change (Sequoia and Kings Canyon National Parks 1999). The stressors with the greatest impact on the parks' flow regimes and water quality are altered fire regimes, air pollution and climate change.

Over 100 years of fire suppression polices have altered fire regimes in the Sierra Nevada Network parks. In general, fire frequencies have decreased and the potential for higher severity wildfires has increased (Swetnam 1993, Caprio and Lineback 1997, Caprio 2004). Potential effects on water resources from a lack of fire are reduced stream flows, changes in biogeochemical cycling and decreased nutrient inputs to aquatic systems (Chorover et al. 1994, Williams and Melack 1997b, Hauer and Spencer 1998, Moore 2000). Less frequent but higher severity wildfires have the potential to impair water resources. Potential impacts include increased flooding, erosion, sediment input, water temperatures, and nutrient and metal concentrations (Tiedemann et al. 1978, Helvey 1980, Riggan et al. 1994, Mac Donald and Stednick 2003). Deposition of ash particles in the surrounding landscape may contribute to increasing nutrient inputs to oligotrophic waters (Spencer et al. 2003).

Since 1968 and 1970, Sequoia and Kings Canyon, and Yosemite National Parks have used fire extensively as a tool to reduce fuel loads and restore the natural processes of fire to park ecosystems (Caprio 1999). Although the parks' fire management programs made significant progress in the last 35 years, altered fire regimes are still considered one of the largest threats to the parks’ ecosystems (Sequoia and Kings Canyon National Parks 1999). Water quality research in the parks has focused on the effects of prescribed burning on hydrology, stream chemistry and nutrient cycles. Increases in stream flows and solute concentrations were detected following prescribed fires in headwater streams of Sequoia National Park (Williams and Melack 1997b, Heard 2005). However, solute concentrations were still well below levels that would threaten aquatic ecosystems. Long-term monitoring with repeated prescribed burning are needed to determine if these increases were within the natural range of variability. Effects of prescribed burning on stream flows or water quality have not been detected at the landscape scale (Heard 2005). The effects of a large, high-severity wildfire are likely to be more pronounced and detectable at larger scales.

The western slope of the central and southern Sierra Nevada is impacted by some of the worst air pollution in the United States (Cahill et al. 1996). Contaminants and nutrients, produced from agricultural, urban, and industrial sources in the San Francisco Bay Area and the Central Valley, are transported by air currents into the Sierra Nevada where they are deposited as wet or dry deposition. High elevation lakes and streams in the Sierra Nevada are oligotrophic, have a low buffering capacity, and sensitive to change from atmospheric deposition of nutrients, toxic substances, and acids. Increased nitrogen and phosphorous inputs are contributing to eutrophication, changes in nutrient cycles and shifts in phytoplankton communities in Sierra Nevada lakes (Goldman et al. 1993, Sickman et al. 2003). Pesticides from the adjacent Central Valley (LeNoir et al. 1999) and global sources (National Park Service Air Resources Division 2003) have been detected in Sierra Nevada streams and lakes at all elevations. The extent of the effects on aquatic ecosystems is largely unknown; however, current research suggests that pesticides may be a threat to aquatic species, including declining amphibian populations (Sparling et al. 2001, Davidson and Shaffer 2002). At a recent water resources scoping meeting in Sequoia and Kings Canyon, participants identified atmospheric transport of contaminants into the parks as one of the top threats to aquatic resources. Episodic acidification from acid neutralizing capacity (ANC) depression during snowmelt and increased nitrate deposition is also a potential threat, although Sierra Nevada waters appear to be fairly resilient and able to buffer current and potentially increased inputs (Leydecker et al. 1999).

Global temperatures have increased over the last century. Climatologists and atmospheric scientists have attributed at least part of this increase to anthropogenic inputs of greenhouse gases (Houghton et al. 1996). Greenhouse gas concentrations and global temperatures are expected to continue to rise. It is predicted that even a modest temperature increase (2.5 °C) will significantly alter hydrologic processes. The most pronounced changes are earlier snowmelt runoff, reduced summer base flows and soil moisture, (Dettinger et al. 2004), a lower snowpack volume at mid-elevations (Knowles and Cayan 2001), and increased flooding, including rain-on-snow events. The water infrastructure in California was built under the assumption that the Sierra Nevada snowpack would act as a temporary reservoir for the State’s water and release it slowly during the spring and early summer months. Changes in precipitation type and timing will result in longer and drier summers with less water available during the months it is most needed. Water quality would be threatened by increased flooding and erosion and lower summer flows. Prolonged summer drought would increase the potential for high severity wildfires, further threatening water quality.

METHODS AND APPROACH

We used the following approach to evaluate existing water resources information for the network parks: 1) perform an extensive literature search and compilation, 2) identify and retrieve existing data sets, 3) identify long-term records for trend analyses, and 4) use the existing information to identify specific water resource issues and current and emerging threats to aquatic ecosystems.

Since water resources information is a broad topic that spans multiple disciplines, we established guidelines to focus the literature search and data retrieval efforts on water quantity and water quality information in the network parks. The guidelines were as follows:

- Include references and data sets for air, geological and biological resources research and monitoring projects only if stream flow or water quality parameters were also measured.
- Include a list with brief descriptions of active meteorological and air quality monitoring sites.
- Do not include fish, macroinvertebrates, and aquatic plants unless 1) water quality or quantity issues were also addressed (i.e. temperature, nutrients) 2) the water body was somehow altered (i.e. dams and holding ponds) or 3) bio-monitoring as an indicator of water quality was specifically addressed.

Sequoia, Kings Canyon, and Yosemite National Park boundaries include most of the headwater streams for the park watersheds. Therefore, we focused on information within the park boundaries. Devils Postpile National Monument does not include the headwaters of the Middle Fork of the San Joaquin River; upstream waterbodies are managed by the Inyo National Forest. For this park, we captured information for waterbodies both within the monument and upstream. We included downstream information for all the parks if it was located near the park boundary, was of especially high value, or was the best available information for the watershed.

LITERATURE REVIEW

We conducted an extensive literature search for the Sierra Nevada Network parks by querying existing databases, websites, park managers and researchers. The results are stored in an EndNote 5.0 library titled *SIEN Water* and include references from the following databases: NRBIB, USGS/ Sequoia and Kings Canyon Field Station Procite database, ISI Web of Science, Water Resources Abstracts (Cambridge Scientific Abstracts), GeoRef (Cambridge Scientific Abstracts), and Ecology Abstracts (Cambridge Scientific Abstracts). Additional sources include the Environmental Protection Agency and State of California websites, I&M project database and results from water quality scoping meetings.

DATA RETRIEVAL

The Water Resources Division of the National Park Service did a thorough search for existing water quality data in all four network parks during the 1990s and results are available in the Baseline Water Quality Data Inventory and Analysis reports (National Park Service 1994, National Park Service 1997, National Park Service 1998). As part of this effort, they organized all the raw data in Visual dBase databases. The Water Resource Division also summarized the presence/absence and distribution of Servicewide Inventory and Monitoring Program “Level 1” water quality parameter groups. Four of these parameters (temperature, specific conductance, pH and dissolved oxygen) are considered ‘core parameters’ and will be monitored servicewide (National Park Service- Freshwater Workgroup Subcommittee 2002) (Table 1). Gaging station locations with available metadata were identified. However, flow data associated with these sites were not included; only flow data associated with water quality samples were reported. The Baseline Water Quality Reports and associated databases were used as a starting point for identifying historic water data sets.

Table 1: Level 1 water quality parameter groups. Bolded parameters are the core parameters that all the networks are required to monitor.

- **Temperature**
- **pH**
- **Conductivity**
- **Dissolved Oxygen**
- Alkalinity
- Flow
- Bacteria
- Toxic Elements
- Clarity/Turbidity
- Nitrate/Nitrogen
- Phosphate/Phosphorous
- Chlorophyll
- Sulfates

We then conducted extensive searches in each park to identify and retrieve additional water quantity and water quality data sets. Searches included national water quality databases, local park databases, computer files, the *SIEN Water* digital library, and the results of water quality scoping meetings. We also contacted park managers, outside researchers and state agencies for additional information and data sets.

We queried national databases that included STORET Legacy and Modernized STORET, maintained by the Environmental Protection Agency (Environmental Protection Agency 2003), and the National Water Information System database (NWIS Web), maintained by the U. S. Geological Survey (U. S. Geological Survey 2003). The Baseline Water Quality Reports captured the STORET Legacy data through the period of record identified in each report. As a result, STORET queries were restricted to post Baseline Water Quality report dates. STORET Legacy and Modernized STORET were queried by Hydrologic Unit Code (HUC), county and latitude and longitude polygons. NWIS Web was queried by HUC and latitude and longitude polygons. All data including the Baseline Water Quality Reports and NWIS data sets are in MS Access databases.

Concurrently, an interagency agreement with the USGS-WRD was initiated to develop and populate a water quality geodatabase for the Sierra Nevada Network. USGS uploaded STORET and NWIS data to the SIEN geodatabase. Additional data compiled as part of this report was also uploaded. The Sierra Nevada Network water quality geodatabase contains existing water quality data in one MS Access database.

TREND ANALYSES

We selected long-term data sets that met specific criteria for temporal trend analyses. The data sets had to have a period of record greater than five years and a sample size greater than 50. Protocols, metadata and QA/QC reports needed to be well documented. Time series and box plots were used to further evaluate the quality of data and to identify any erroneous data points.

Stream chemistry data were tested for temporal trends using the Seasonal Kendall Test modified to account for serial correlation ($\alpha = 0.05$) (Hirsch and Slack 1984). The Sen Slope method was used to estimate magnitude of the trends. Three to four seasons were defined for each site based on the hydrology and seasonal variability of solute concentrations. Selected seasons had to meet the requirement that a minimum of 50% of the possible comparisons needed to be made for 80% of the seasons. Raw and flow-adjusted concentrations were both tested. Flow-adjusted concentrations were tested by modeling the variation due to discharge using a loess routine and conducting trend analyses on the residuals. Statistical analyses were performed using S-Plus 6.1 with the USGS S-ESTREND library (Slack et al. 2003).

DEVILS POSTPILE NATIONAL MONUMENT

Devils Postpile National Monument encompasses 320 hectares in the upper Middle Fork of the San Joaquin watershed in the central Sierra Nevada. The monument was established in 1911 to protect two prominent geologic features, the Devils Postpile formation and Rainbow Falls (Huber and Eckhardt 2002). The Postpile is a mass of 18 m high polygonal basalt columns that were formed from a cooling lava flow over 100,000 years ago. Rainbow Falls is a 31 m water fall along the Middle Fork of the San Joaquin River. Elevations in the monument range from 2,200 to 2,500 meters. The vegetation type is montane forest dominated by red fir (A*bies magnifica*) and lodgepole pine (*Pinus contorta*). Three-quarters of the monument lands are included in the Ansel Adams Wilderness and surrounding lands are managed by the Inyo National Forest, under the USDA Forest Service.

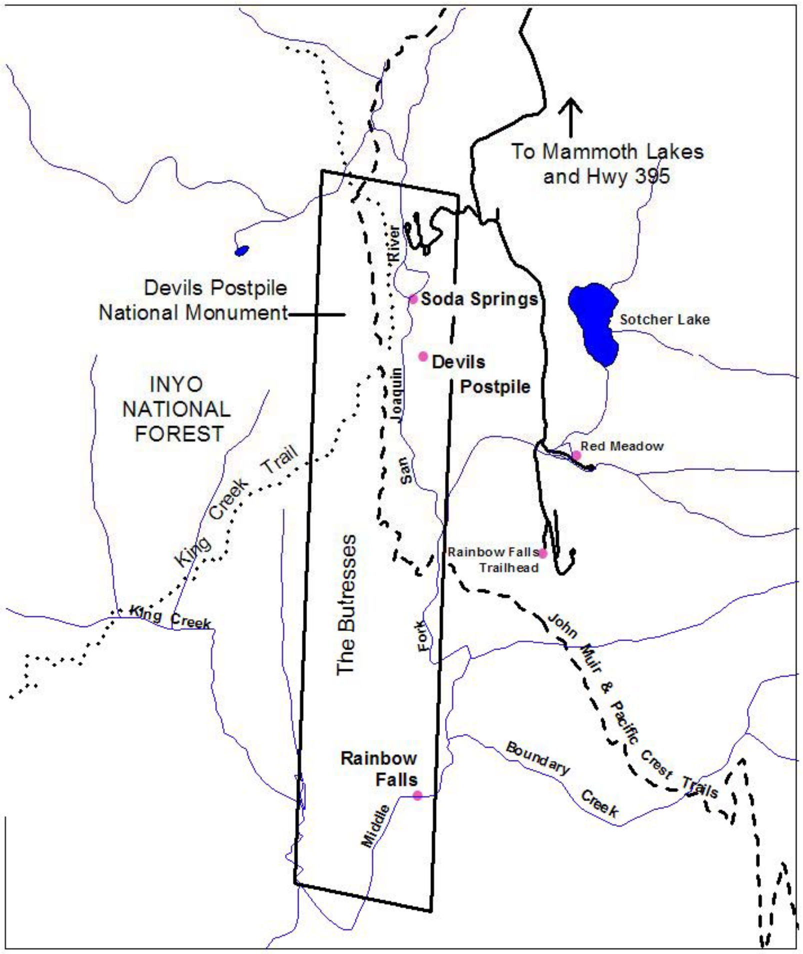
WATER RESOURCES

Devils Postpile National Monument is located entirely in the upper Middle Fork of the San Joaquin watershed. It is the only park in the network where the headwater streams are not included in the park boundary. The headwaters of the Middle Fork of the San Joaquin begin 14.1 km upstream of the monument at Thousand Island Lake. The watershed area above the monument is managed by Inyo National Forest.

The monument has 5.9 km of rivers and streams including the Middle Fork of the San Joaquin River, and short sections of King Creek and an un-named creek, both tributaries to the San Joaquin (Figure 3). The Middle Fork of the San Joaquin River travels the length of the monument and plunges 31 m over Rainbow Falls before crossing the southern boundary. Carbonated mineral springs are located in Soda Springs Meadow, near the ranger station and campground facilities.

There are no impoundments or diversions within the monument boundary. The public water supply is pumped from a well near the Middle Fork of the San Joaquin (Appendix 1). Small water diversions or active wells exist upstream near U. S. Forest Service campgrounds.

Figure 3: Lakes, rivers, and streams in and near Devils Postpile National Monument.



HYDROLOGIC AND WATER QUALITY DATA SETS

Water Quantity

Water quantity data for Devils Postpile National Monument are limited. Historically, stream flow was not continuously monitored within or near the monument boundary (Rowan et al. 1996, National Park Service 1998). The nearest historic gaging station was located on the Middle Fork of the San Joaquin River at Millers Crossing, approximately 15 km downstream from the boundary. Flow data from 1921-1991 are available from NWIS Web (Appendix 2).

The first collection of stream flow data in the monument began in 1994. A staff gage was installed along the Middle Fork of the San Joaquin River near the Devils Postpile formation and a stage-discharge relationship developed. National Park Service rangers recorded staff gage measurements during routine patrols (Rowan et al. 1996).

Queries in NWIS Web also identified one well just outside the northeast corner of the park boundary. No monitoring data were available through the NWIS Web site.

Water Quality

Existing water quality data for Devils Postpile and all upstream waterbodies are located in four main data sets: the Baseline Water Quality Report, STORET Legacy, Fishery and Riparian Resources of Devils Postpile National Monument and Surrounding Waters report, and the Non-point Source Water Quality Monitoring, Inyo National Forest, 1975 report (Table 2).

Table 2: Historical water quality data sets for Devils Postpile National Monument and upstream waters.

Data Set	Agency	Beg. Year	End Year	No. Records
Horizon Report	NPS	1980	1997	358
STORET: Upper San Joaquin	EPA	1980	1985	38
Fishery and Riparion Resources Assessment	Fish and Game	1994	199	
Water quality monitoring, Inyo National Forest	UCLA/UCD	1975	1975	

The Baseline Water Quality Report includes 358 water quality records from 1980 -1997. Sixty-seven of these records are from samples taken within the monument boundary. The remaining 291 records are within the larger study area, which was defined as 3 miles upstream and 1 mile downstream of the park boundary. Water quality records exist for 9 of the 13 Inventory and Monitoring Level 1 parameters. Data do not exist for the dissolved oxygen, flow, chlorophyll, and bacteria parameter groups. The data captured in the Baseline Water Quality Reports are from 19 different sites and are associated with four specific monitoring projects.

- California Department of Fish and Game monitored eight of the sites as part of a statewide monitoring program to assess fish populations. They measured pH, conductivity, temperature, and alkalinity during the 1980s and 1990s.

- The Environmental Protection Agency measured 26 water quality parameters in Iceburg Lake and Nydiver Lakes (middle) as part of the 1985 Western Lake Survey. The project objectives were to 1) identify lakes in potentially sensitive areas that were acidic, 2) identify lakes in potentially sensitive areas that had low acid neutralizing capacity (ANC), and 3) determine the chemical characteristics of lake populations (Blick et al. 1987a).

- The Department of Energy sampled four sites during August of 1980 as part of the National Uranium Resource Evaluation (U. S. Geological Survey 2001). This was a national project initiated in 1973 to identify uranium resources in the United States. They sampled 15-24 water quality parameters, including metal concentrations.

- Four springs were monitored in the 1980’s and 1990’s for multiple water quality parameters. Associated projects and monitoring agencies are not known.

STORET Legacy contains water quality data for two additional sites in the upper San Joaquin that were not captured in the Baseline Water Quality Report. These sites were part of the National Uranium Resource Evaluation and are located upstream of the monument and the Baseline Water Quality Report study area. There are 38 additional records associated with these sites. Modernized STORET does not contain any records for the upper watershed.

The Fishery and Riparian Resources of Devils Postpile National Monument and Surrounding Waters report (Rowan et al. 1996) summarizes and augments existing fishery and riparian information for the Devils Postpile area. This survey led to the designation of the Middle Fork of the San Joaquin River within Devils Postpile as a Wild Trout Water by the California Department of Fish and Game. As part of this project, researchers installed the Middle Fork of the San Joaquin River staff gage and collected additional water quality data for 12 sites. Parameters included stream flow, water temperature (hourly), pH, sediment observations and substrate quality. Researchers measured aquatic macroinvertebrate taxon composition and diversity to assess current and future impacts from anthropogenic disturbances. One component of this study was to assess benthic macroinvertebrate communities. They collected samples using The California Stream Bioassessment Procedure, a biological monitoring tool used to detect change in aquatic systems (Schroeter and Harrington 1995).

The University of California, Davis and the University of California, Los Angeles measured water quality parameters for 34 waterbodies on the Inyo National Forest in 1975 (Baas et al. 1976). The focus of the study was to assess the impact of non-point sources on water quality in wilderness and recreational areas. Four of the study lakes (Shadow, Ediza, Garnet, and Thousand Island) are located in the upper San Joaquin watershed.

WATER RESOURCES MONITORING

In the summer of 2004, Scripps Institute of Oceanography installed a gaging station on the Middle Fork of the San Joaquin River near the pump house. Scripps is currently monitoring stream flows at 39 sites in the upper Merced and Tuolumne watersheds as part of a hydroclimate monitoring network (DiLeo et al. 2003). Installation of the Devils Postpile gaging station is an expansion of this program into the upper San Joaquin watershed.

The next nearest gaging station is downstream from the monument on the San Joaquin River below the Mammoth Pool Reservoir.

Currently, there are no water quality research and monitoring projects in the monument.

LOCAL WATER RESOURCE STATUS AND ISSUES

In the Baseline Water Quality Report data were compared to EPA water quality criteria and instantaneous concentration values selected by the Water Resources Division (National Park Service 1998). Alkalinity exceeded the criterion (100% exceeding) more than any other constituent. Concentrations were below the threshold used by the NPS Air Resources Division to determine potential sensitivity to acid deposition. Consistent with the alkalinity findings, pH values also exceeded (50% exceeding) the lower limit criterion. Dissolved arsenic exceeded (25%) the freshwater acute criterion. The following constituents exceeded the EPA drinking water criteria: total chloride (14%), fluoride (33%), and arsenic (50%). The Water Resources Division had difficulty evaluating current water quality in the monument due to the absence of long-term monitoring data and dissolved oxygen and bacteria data. However, using the limited available data they concluded that water quality generally appears to be good.

The Central Valley Regional Water Quality Control Board considers water quality in Sierra Nevada headwater streams to be good to excellent and suitable for all beneficial uses (California Regional Water Quality Control Board Central Valley Region 1998). Devils Postpile National Monument and the upstream watershed do not contain any 303(d) listed waters (State Water Resources Control Board 2002).

The town of Mammoth Lakes is proposing to pump groundwater from the San Joaquin Ridge. This action could reduce annual flows in the Middle Fork of the San Joaquin River in Devils Postpile, although impacts are unknown (National Park Service 2002a).

Visitor use impacts in the monument and upstream at U. S. Forest Service campgrounds are a potential threat to water quantity and quality. Specific concerns identified during scoping meetings and by park managers include upstream diversions, stream bottom litter, human waste, stream bank degradation and increased runoff where vegetation is sparse (National Park Service 2003b).

Managers identified arsenic, from volcanic sources, as a potential threat to the Devils Postpile drinking water supply. Dissolved arsenic concentrations in park waters have exceeded EPA freshwater acute and drinking water criteria (National Park Service 1998).

Abandoned mines are located throughout the upper San Joaquin watershed. Managers identified acid rock drainage as a potential threat to water quality in Devils Postpile.

Although quantitative fire history studies were just initiated in the Devils Postpile area, managers believe that fire suppression policies have altered fire regimes in the monument forests (Caprio 2004). In 1992, a moderate to high severity wildfire, The Rainbow Fire, burned through 85% of the monument. Ecological effects following this fire were more pronounced and outside the natural range of variability, especially at the lower elevations (Caprio 2004). Effects on water resources appeared to be minimal, but post-fire monitoring of pH, substrate and macroinvertebrates was limited to one year (1994) (Rowan et al. 1996). Long-term effects and effects on other water quality parameters including nutrients and temperature are not known. Due to the high severity of the fire and losses in seed banks, recovery of the vegetation is slow and the long-term effects on stream flow and water quality are uncertain.

SEQUOIA AND KINGS CANYON NATIONAL PARKS

Sequoia and Kings Canyon National Parks encompass 350,169 ha in the southern Sierra Nevada. Eighty-four percent of the parks are designated wilderness. The parks are primarily bordered by Inyo National Forest on the east, Sequoia National Forest on the south, Giant Sequoia National Monument on the south and west and Sierra National Forest on the west and north. Smaller sections of the boundaries are also shared with the Bureau of Land Management and private landowners. Elevations in the park range from 418-4417 m and include a variety of vegetation types that range from chaparral and oak-woodland in the lower elevations to the higher elevation sub-alpine and alpine vegetation. The giant sequoia mixed conifer forests are located in the mid-elevations, 1650-2000 m, along the western slope.

HISTORY

Much like the rest of the West, the Southern Sierra Nevada was first valued for its natural resources, and activities including logging, grazing, and mining. After several years of resource extraction and exploration of the area, word of the spectacular beauty of the landscape and the giant sequoia groves spread across California. As tourism and recreation increased, concern began to be voiced regarding protection. Editorials in local newspapers and talk in San Francisco began to fuel a growing conservation ethic centered on preservation of these mountain landscapes and resources (Strong 1996).

Also during this time, people in the valley dependent on agriculture, were becoming concerned with deterioration of the mountain ecosystem. They especially began to notice the impacts of logging on water resources, which were of vital interest for irrigation (Dilsaver and Tweed 1991). Led by well-known journalist George W. Stewart, and politician John F. Miller, a campaign for protection of the southern Sierra Nevada. Eventually, "…. a bill to provide for setting apart a certain tract of land in the State of California as a public park," was proposed (Dilsaver and Tweed 1991). On September 25, 1890, President Benjamin Harrison signed the bill enabling the protection of two townships and four sections be set aside for “enjoyment of the people,” and Sequoia became the second national park to be established (Strong 1996).

One week after creation of Sequoia was finalized, a second Act was passed, increasing the size of the park by three times. There is speculation that the Southern Pacific Railroad, which acknowledged that the National Park would increase tourism and their own business, wanted further protection of water resources of the San Joaquin Valley (Strong 1996).

Kings Canyon National Park was championed as an addition to Sequoia for many years by the Sierra Club, conservationists, and others. Under control of the Forest Service, there was a conflict of interest between park advocates, and those wanting to augment the water resources with dams for hydroelectric power (Strong 1996). The Kings River remained a valuable resource for valley residents for irrigation, while the city of Los Angeles wanted to harness the potential for hydropower, and others, including the Forest Service, saw the area as a possible tourism destination (Dilsaver and Tweed 1991)

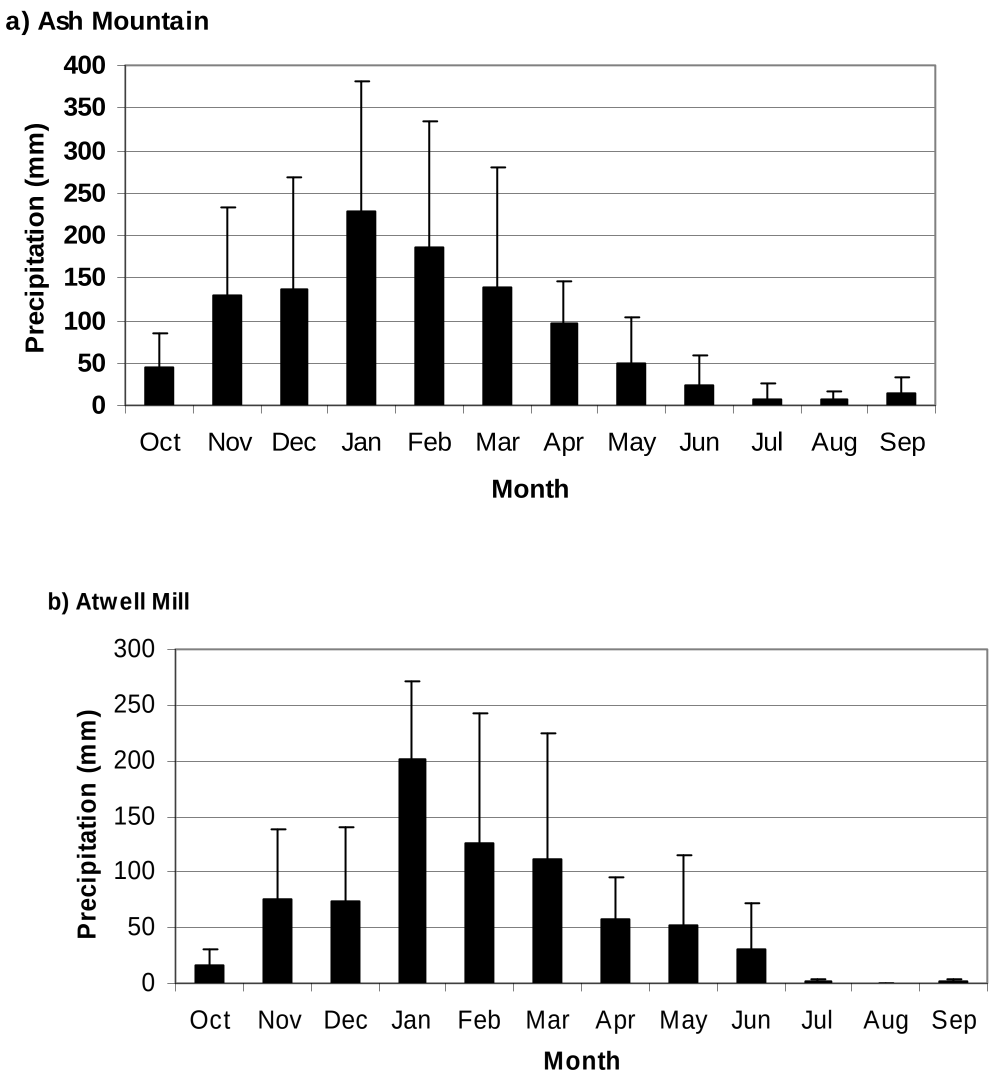
In 1935, the Secretary of the Interior, Harold Ickes, proposed a bill to establish Kings Canyon National Park. He designated the park as one of backcountry and wilderness uses, intending to maintain the park in its natural state. Though this proposal was met with a great deal of initial opposition, Ickes promoted the potential of a tourist magnet, and promised valley residents the necessary water allocation. Appeasing the dissidents of the powerful Kings River Water Association with water projects outside of the park, and with the withdrawal of Los Angeles’s need for water due to the recently completed Boulder Dam on the Colorado River, Ickes was able to create legislation for the creation of the park. On March 4, 1940, Kings Canyon National Park was established when Franklin D Roosevelt signed the bill, adding 450,000 acres of the Sierras to the National Park Service (Strong 1996).

WATER RESOURCES

Sequoia and Kings Canyon National Parks consist of four major watersheds: the Kaweah, Kern, Kings, and San Joaquin. A very small portion of the park is also located in the upper Tule watershed. These watersheds all drain to the west of the Pacific Crest and into California’s Central Valley.

Mean annual precipitation is 92 cm at the middle elevations (National Atmospheric Deposition Program (NRSP-3)/National Trends Network 2004). Most of the precipitation falls during the winter months (Figure 4). The dominant precipitation types are rain at the low elevations and snow at the middle and high elevations.

Figure 4: Mean monthly precipitation at low (Ash Mountain: 535 m) and middle (Atwell Mill: 1975 m) elevations (Sequoia and Kings Canyon National Parks 2002a, U. S. Army Corps of Engineers 2002).

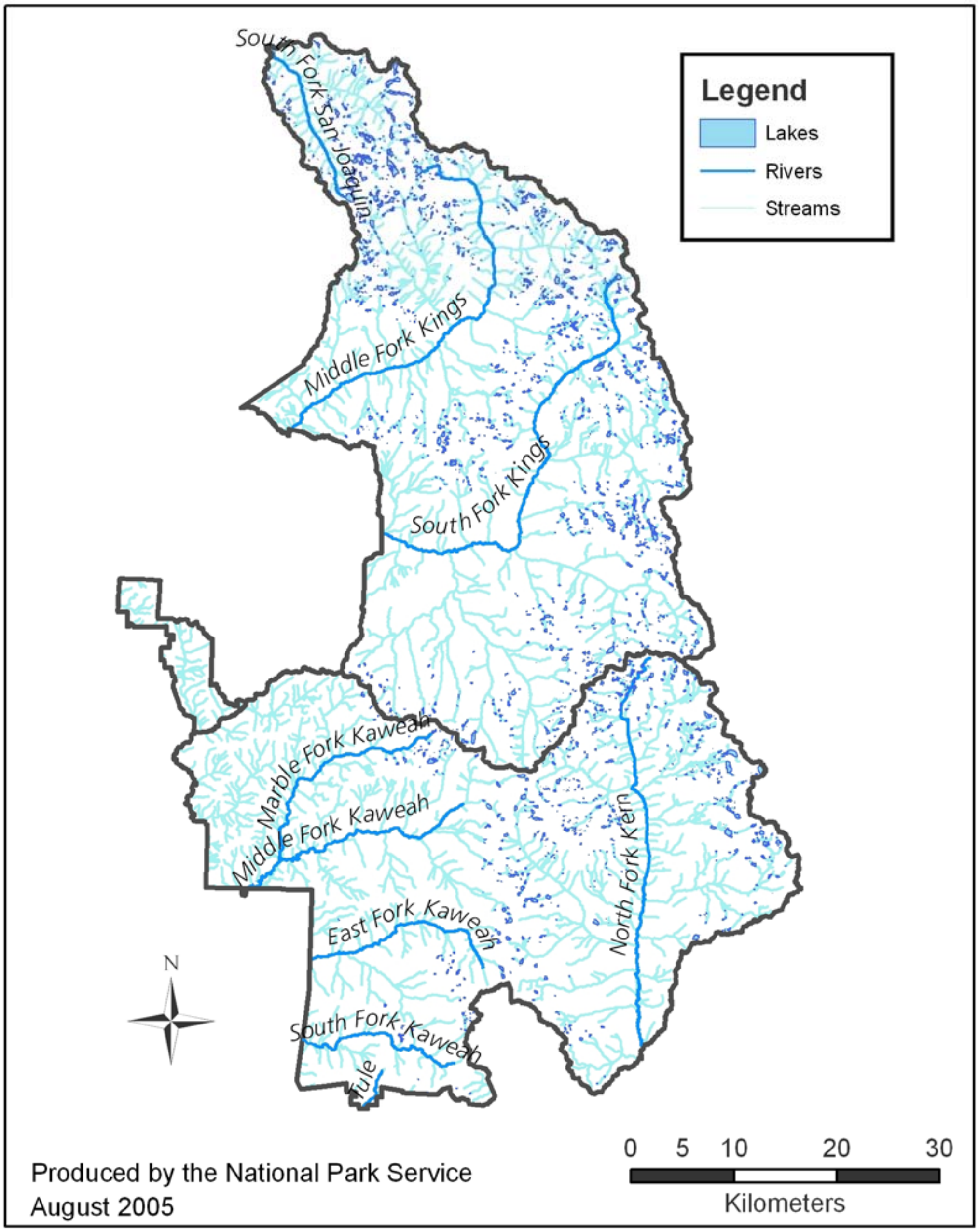


There are approximately 2,650 lakes and ponds and thousands of kilometers of streams and rivers within the parks' boundaries (Sequoia and Kings Canyon National Parks 2002b) (Figure 5). Sequoia and Kings Canyon are also known for their unique cave resources that include underground streams and lakes and karst springs. The parks contain more than 200 caves formed in mesozoic limestone. Additional water resources include cold and hot springs, wet meadows, seeps and ephemeral pools.

Sequoia and Kings Canyon National Parks contain three Wild and Scenic River segments, which include the Middle and South Forks of the Kings River (98.5 km) and the North Fork of the Kern River (46.5 km). Under the Wild and Scenic Rivers Act, the park is required to develop a Comprehensive Management Plan to ensure protection of the river's free flowing status and to protect and enhance the river corridor's outstandingly remarkable values (ORVs). To date, a draft Wild and Scenic River Plan and Study has been developed and incorporated into the draft General Management Plan. After these plans are complete, the park is required to develop user carrying capacities with associated monitoring strategies. Five other rivers within the park, the South Fork of the San Joaquin, and the Marble, Middle, East and South Forks of the Kaweah, were determined to be eligible for the Wild and Scenic River designation (National Park Service 2002b). Proposals to designate these rivers are still in the draft phase.

There are four large impoundments within the park boundary. All four were built on existing lakes in the upper East Fork of the Kaweah in the early 1900s and are currently operated by Southern California Edison. Numerous small impoundments also exist in small creeks primarily used for water supplies. There are at least 18 water diversions and seven wells within the park boundary. Most are small diversions for local water supplies, particularly in the Mineral King area. There are likely additional diversions and wells within the park associated with private in-holdings. Southern California Edison holds the water rights for the two largest diversions, located on the Middle Fork and Marble Fork of the Kaweah near Potwisha Campground (Appendix 1).

Figure 5: Lakes, rivers, and streams in Sequoia and Kings Canyon National Parks.



HYDROLOGIC AND WATER QUALITY DATASETS

The Water Resources Division of the National Park Service conducted a search for existing water resources data in and near Sequoia and Kings Canyon National Parks during the 1990s. The results are summarized in the Baseline Water Quality Data Inventory and Analysis report (National Park Service 1997). Thirty-one gaging stations were documented, with 19 inside the park boundary. NPS-WRD retrieved 66,040 water quality records that date from 1951-1994. 56,665 of these records are located within the parks boundaries. Water quality records exist for 13 of the 14 Inventory and Monitoring Level 1 parameters. Data were not identified for the chlorophyll parameter group.

Historic flow data are available from 24 gaging stations in or near the parks (Appendix 2). Twenty-three of the stations were located in the Kaweah River drainage, and one historic site was located on the South Fork of the Kings River near Cedar Grove.

Queries in the Environmental Protection Agency's STORET Legacy database revealed many water quality records for Sequoia and Kings Canyon National Parks; however, all of these records were already captured by NPS-WRD in the Baseline Water Quality Report. Queries in EPA's Modernized STORET determined that no Sequoia and Kings Canyon records are currently stored in the database. The USGS National Water Information System (NWIS Web) database was also queried and an additional 10,724 water quality records were retrieved. A comparison between NWIS and Baseline Water Quality Report data determined there was overlap between the two databases. Of the 10,724 records in NWIS Web, 2,241 are unique records that were not captured in the Baseline Water Quality Report. There are nine additional water quality data sets identified during local searches in the park and with co-operating agencies (Table 3).

Table 3: Water quality data sets compiled for Sequoia and Kings Canyon National Parks.

Data Set	Agency	Beg. Year	End Year	No. Records
Horizon Report	NPS	1951	1994	66040*
NWIS	USGS	1960	1980	10724*
SEKI Watershed Program	NPS/ USGS	1983	2003	6,650
Western Lakes Survey	USGS/ EPA	1999	1999	
Lake inflow chemistry (7 lakes study)	UCSB	1983	2000	935
Lake outflow chemistry (7 lakes study)	UCSB	1986	2001	1,517
Lake chemistry (7 lakes study)	UCSB	1982	1995	1,144
Marble Fork Kaweah (Tokopah and Potwisha)	UCSB	1993	2000	890
Emerald Lake Outflow	UCSB	1983	2001	199
Sierra Episodes Study	UCSB	1993	1994	340
Amphibian/high elevation lake Inventory	UCSB SNARL	1999	2001	
SWAMP	RWQCB	2002	2003	55

* A record in the marked data sets (*) contains one paramter for one sample. For the other data sets, one record contains one sample that may have multiple parameters.

WATER RESOURCES MONITORING

Numerous water quantity and water quality studies have been conducted at Sequoia and Kings Canyon National Parks. The literature search for these parks captured 317 references that included 91 journal publications. I identified 12 long-term studies and several additional studies that may be of particular value to the Inventory and Monitoring Program (Table 4).

Table 4: Long-term monitoring sites in Sequoia and Kings Canyon National Parks.

Site Name	Period of Record	Water Quality	Flow
Chamise Creek	1985-2000, 2002-present	x	x
Tharp's Creek	1984-2000, 2003-present	x	x
Log Creek	1984-2000, 2003-present	x	x
Emerald Lake outflow	1984-present	x	x
Marble Fork Kaweah- above Tokopah	1993-present	x	x
Topaz Lake outflow	1987-present	x	x
East Fork Kaweah- nr Look Out Pt	1995-present	x	
Trauger's Creek	1995-present	x	x
Deadwood Creek	1995-present	x	x
Middle Fork Kaweah - at Potwisha	1949-present		x
Marble Fork Kaweah- at Potwisha	1950-present		x
East Fork Kaweah - nr 3 Rivers	1952-present		x

Long-term Monitoring in the Middle Fork of the Kaweah Watershed

As part of the Sequoia and Kings Canyon Watershed Research Program, which was a cooperative effort between the National Park Service, U. S. Geological Survey and UC Santa Barbara, four long-term watershed study sites were established along an elevational gradient in the Middle Fork of the Kaweah watershed (U. S. Geological Survey - Biological Resources Division 2000). The sites, which include Chamise Creek (750m) in the chaparral vegetation zone, Tharp's Creek (2067m) and Log Creek (2067m), both in the mixed conifer zone, and Emerald Lake Outflow (2807m) in the subalpine zone, were established between 1983 and 1985. Although there were some gaps in data collection, the records remain relatively continuous through present day. Stream flow and stream chemistry (pH, ANC, conductivity, nutrients and major anions and cations) were collected as part of air pollution, climate change and fire research studies.

Research in the sub-alpine zone, near the Emerald Lake watershed site was expanded to include two other sites in the larger Tokopah watershed, the Marble Fork of the Kaweah and Topaz Lake. The Emerald Lake basin is one of the most thoroughly studied subalpine watersheds in the world. The literature search captured 87 publications and reports resulting from research in the Tokopah watershed.

In 2003, the US Geological Survey-Water Resources Division established a Hydrologic Benchmark Network (HBN) site on the Marble Fork of the Kaweah River above Tokopah Falls. The HBN is a national program that monitors minimally disturbed watersheds for long-term trends in streamflow and water quality (U. S. Geological Survey 2000). This site is co-located with UC Santa Barbara's study site.

East Fork of the Kaweah Watershed

In the East Fork of the Kaweah, Colorado State University and the Sequoia and Kings Canyon Watershed Research Program investigated the individual and cumulative effects of landscape scale prescribed fire on hydrology and stream chemistry at different spatial and temporal scales. To investigate the potential effects of prescribed fire at different scales, water quality parameters were measured in the large (i.e. 20,000 ha East Fork Kaweah) watershed and in two small (i.e. 100 ha Deadwood and Trauger's) watersheds nested in the larger watershed.

Deadwood, the 100 ha watershed, was treated with a single prescribed fire that burned 60% of the watershed area. Water yield was not affected by the burn. Changes in stream chemistry were detected for specific conductance, ANC, chloride, sulfate, calcium, sodium, potassium nitrate, and phosphate. The East Fork, the 20,000 ha watershed, was treated with eight prescribed fires staggered over seven years that burned 11% of the watershed area. Changes in hydrology and stream chemistry were not detected at the landscape scale. Effects of large scale prescribed burning are more pronounced in headwater streams than at the landscape scale. Differences were attributed to smaller percent watershed and riparian areas burned in the 20,000 ha watershed. Results from this study indicate that treatments must be larger or more frequent than burning 11% of the watershed area over seven years before detectable changes in water yield and stream chemistry at landscape scales occur (Heard 2005).

South Fork of the Kings River

The Central Valley Regional Water Quality Control Board is monitoring the South Fork of the Kings River for nutrients and pathogens as part of the State's Surface Water Ambient Monitoring Program (SWAMP) (Bufort in progress). Data will eventually be uploaded to STORET.

Drinking Water Monitoring

The Sequoia and Kings Canyon Branch of Public Health monitors water quality for drinking water sources and wastewater discharge effluent. Currently, source water monitoring is conducted at approximately thirteen sites in the parks. Detailed source location data are not widely published for security reasons; however, more information can be obtained from the parks' Public Health Sanitarian. Front country drinking water sources are monitored for total coliform, escherichia coli (most probable number/100ml), general minerals, general physical and inorganic chemical parameters. Monitoring frequency is dependent on the classification of the water system and the source (National Park Service 1999, Schwarz 2004). Results are stored in an Access database and summarized in annual Consumer Confidence Reports. There are at least seven spray and leach fields in the parks. Discharge effluent is monitored weekly for total coliform, fecal coliform, settleable solids, suspended solids, and biochemical oxygen demand. Wells located at the Clover Creek disposal area are sampled twice a year for total coliform and escherichia coli (Schwarz 2004).

Long-term USGS Gaging Stations

Three USGS gaging stations, operated in conjunction with Southern California Edison, have over 50 years of discharge data for the Marble, Middle and East Forks of the Kaweah.

Currently, there are ten active gaging stations in the Sequoia and Kings Canyon National Parks (Appendix 2) and fourteen research and monitoring projects addressing water quantity and water quality issues (Appendix 3).

The US Geological Survey in conjunction with Southern California Edison operates two gaging stations, located on the lower Middle and Marble Forks of the Kaweah River. The National Park Service and UC Santa Barbara maintain the eight other stations which are used to gage smaller watersheds (13-1900 ha) associated with research studies. These sites include Chamise, Tharp's, Log, Emerald Outflow, Topaz Outflow, Marble Fork Kaweah above Tokopah, Trauger's, and Deadwood. Continued operation of these eight research watersheds is dependent on research needs and funding.

The US Geological Survey in conjunction with Southern California Edison also operates two gaging stations located just outside of the park. The East Fork of the Kaweah and the Main Fork of the Kaweah are gaged just downstream from the park boundary.

The Kern and Kings Rivers are not gaged near the park boundary. The nearest station on the South Fork of the San Joaquin is below the Florence Lake reservoir, approximately 12 km downstream. Specific station information and metadata were not compiled for these sites; however, data are available from NWIS Web.

Currently, the parks have 14 meteorological stations, five air quality monitoring sites, and 29 snow sensor and survey courses (Appendix 5). Detailed information regarding these sites is available from the Inventory and Monitoring Program's Project database or directly from the Sequoia and Kings Canyon Air Resources Branch.

CURRENT RESEARCH PROJECTS

Four research projects are investigating the effects of prescribed fire on aquatic systems (Additional information is listed in Appendix 3):

- Park staff members are continuing to monitor hydrology and stream chemistry in Tharp's and Log Creeks in order to study the effects of a prescribed fire re-burn in the Tharp's watershed.

- The park staff is also working with US Geological Survey- Biological Resources Division and UC Santa Barbara to summarize existing data and produce several publications addressing long-term research in the Tharp's and Log watersheds (Engle and Melack in prep).

- Colorado State University is investigating the effects of landscape scale prescribed burning on hydrology and stream chemistry in the East Fork of the Kaweah (Heard in prep).

- UC Berkley has a project in the East Fork of the Kaweah studying the effects of prescribed fire on aquatic macroinvertebrates, periphyton, channel morphology, hydrology, large woody debris, and riparian vegetation in headwater streams (Rogers in progress).

Four projects are studying the effects of air pollution (pesticide and nitrogen deposition) on aquatic resources:

- The Environmental Protection Agency is studying the distribution of agricultural contaminants in relation to the decline of the mountain yellow legged frog (*Rana muscosa*) in Sequoia and Kings Canyon National Parks and the Sierra National Forest (Bradford in progress).

- Texas A&M University and the U. S. Geological Survey are investigating the effects of pesticides on Pacific treefrog tadpoles along a north-south transect in the Sierra Nevada. Researchers translocated and placed tadpoles in chambers among sites located in Sequoia, Yosemite and Lassen National Parks (Sparling and Cowman 2003).

- The Western Airborne Contaminants Assessment Project (WACAP) is a cooperative effort between multiple agencies and universities to study persistent organic pollutants in western National Parks. Pear and Emerald lakes, in Sequoia National Park, were chosen as two of the WACAP sites (Landers in progress).

- UC Santa Barbara is investigating biogeochemical and hydrological mechanisms that influence the extent of nitrogen-limitation in alpine and chaparral ecosystems. Their study will further our understanding of how increased nitrogen deposition and climate change will affect nitrogen cycling in these ecosystems (Melack et al. 2002).

Portland State University is inventorying and mapping glaciers in Sequoia and Kings Canyon, Yosemite and the surrounding national forests (Basagic in progress). Information from this study will help managers understand how climate affects hydrologic processes in the Sierra Nevada.

University of California, Davis is investigating the prevalence and concentration of coliform bacteria in Sierra Nevada wilderness area lakes and streams. Researchers will collect water samples from over 120 lakes and streams, including waterbodies in Sequoia and Kings Canyon National Parks (Derlet 2004).

Western Kentucky University and the National Park Service are measuring stream stage, conductivity, pH, and temperature in Tufa Falls Creek, located in the East Fork of the Kaweah watershed. This research will contribute to the overall understanding of the role of karst systems in global carbon budgets (Despain in progress).

LOCAL WATER RESOURCE ISSUES

In the Baseline Water Quality Report water quality data were compared to EPA water quality criteria and instantaneous concentration values selected by the Water Resources Division (National Park Service 1997). Alkalinity exceeded the criteria (99% exceeding) more than any other constituent. Concentrations were below the threshold used by the NPS Air Resources Division to determine potential sensitivity to acid deposition. Consistent with the alkalinity findings, pH values also exceeded (49% exceeding) the lower limit criterion. The following constituents were found to exceed criteria for freshwater aquatic life: dissolved oxygen (9%), turbidity (1%), cadmium (7%), mercury (3%), and zinc (1%). The following constituents exceeded EPA drinking water criteria: chloride (<1%), cadmium (4%), lead (18%), and mercury (11%). Total coliform (14%) and fecal coliform (21%) values exceeded criteria for freshwater bathing. The Water Resources Division had difficulty evaluating current water quality in the parks due to a lack of data after 1985. However, using limited available data they concluded that water quality generally appears to be good.

The State initiated the Surface Water Ambient Monitoring Program (SWAMP) in 1999 to assess California's waters. As part of this program, Regional Water Quality Control Boards (RWQCBs) are monitoring water quality to determine if waters should be listed as 303(d) waters. Due to the outstanding water quality, Sequoia and Kings Canyon National Parks do not have any water bodies that are listed (State Water Resources Control Board 2002). However, the South Fork of the Kings River near the park boundary was selected for preliminary monitoring of nutrients and pathogens. Preliminary results from SWAMP indicate that concentrations are low and the South Fork of the Kings will not be considered for 303(d) listing (P. Bufort, oral comm., 2003). The Central Valley RWQCB considers water quality in the parks to be good to excellent and suitable for all beneficial uses (California Regional Water Quality Control Board Central Valley Region 1995). In general, the Basin Plans and 305(b) report are primarily concerned with river segments below the foothill dams and groundwater in the Central Valley.

Other local issues of concern for SEKI identified during recent water resources scoping meetings include:

Water quantity can be a problem for the Grant Grove water supply, which consists of two wells and two springs. In addition, water rights for these sources may not be secured by the park.

Potential acid rock drainage from abandoned mines in the Mineral King area of Sequoia National Park could degrade water quality in the East Fork of the Kaweah. Impacts on water quality have been observed from one mine in the park. Impacts from other mines and cumulative impacts at a larger scale have not been quantified.

High concentrations of nutrients and bacteria from spray fields can move into receiving stream waters. Monitoring in streams near the Red Fir and former Giant Forest spray fields detected increased nutrient concentrations up to 3 km downstream of the sites (Sequoia and Kings Canyon National Parks 1999). There are a minimum of seven spray fields in the park.

There was expressed concern about the effects of pharmaceuticals on park waters. While effects maybe more pronounced in urban areas well downstream of the park boundaries, there is currently no information on whether pharmaceuticals occur in the parks in sufficient concentrations to have chemical or biological effects on humans or ecosystems.

There are little data available on the impacts of the impoundments and diversions within the park. Since these structures alter flow regimes and have the potential to degrade water quality, park managers identified this as an area of high concern (see earlier *Water Resources* section and Appendix 1 for descriptions of the impoundments, diversions, and wells).

YOSEMITE NATIONAL PARK

WATER RESOURCES

Yosemite National Park consists of two major watersheds: the Tuolumne and Merced. It also contains a small portion (130 ha) of the Fresno River watershed. These rivers drain to the west into the Central Valley and eventually the Sacramento-San Joaquin Delta (Figure 6).

Mean annual precipitation is 914 mm in Yosemite Valley (1,220 m) and 1270 mm in Tuolumne Meadows (2650 m). Most of the precipitation falls during the winter months. Dominant precipitation types are rain at low elevations and snow at middle and high elevations.

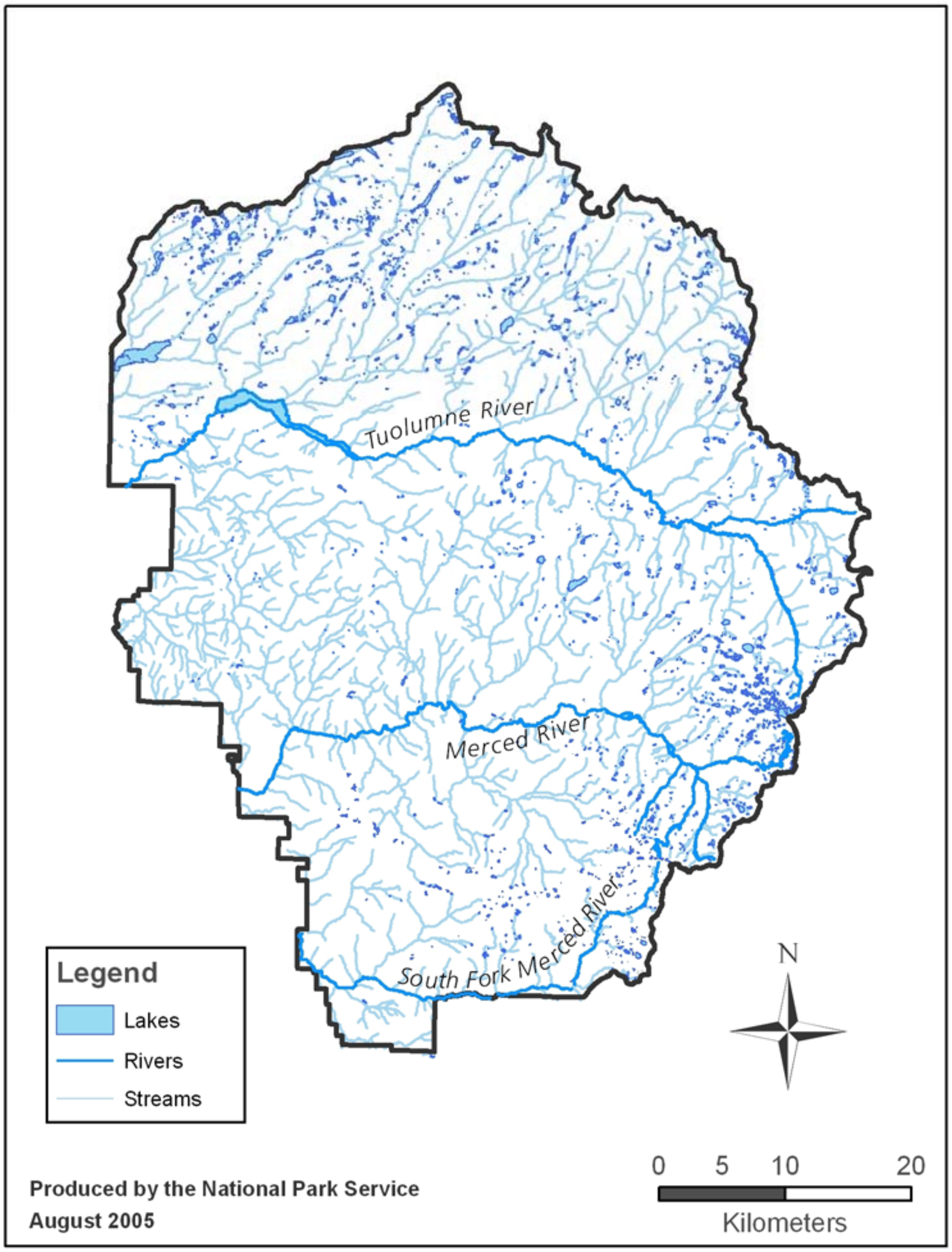
There are approximately 1,600 lakes (surface area greater than 0.0073 ha) and thousands of kilometers of streams and rivers within the park boundaries. Yosemite Valley is known for some of the most scenic and tallest waterfalls in the world; Yosemite falls drops 739 m before it hits the valley floor and flows into the Merced River. Additional water resources include springs, wet meadows, including peat meadows, seeps and ephemeral pools.

There are two Wild and Scenic Rivers, the Merced (130.0 km) and Tuolumne (87.0 km) Rivers, in Yosemite. Under the Wild and Scenic Rivers Act, the park is required to develop a Comprehensive Management Plan to ensure protection of the river's free flowing status and to protect and enhance the river corridor's outstandingly remarkable values (ORVs). The management plan for the Merced Wild and Scenic River—the Merced River Plan— is near completion. Monitoring along the Yosemite Valley segments was initiated in 2004. The park is in the early stages of planning for the Tuolumne River Plan; this management plan is scheduled to be complete in 2008.

The park contains two major impoundments: Hetch Hetchy (4.45×10^8 m^3) and Lake Eleanor (3.34×10^7 m^3). Hetch Hetchy, which impounds the Tuolumne River, was created in 1938 with the completion of O'Shaughnessy Dam. Hetch Hetchy Reservoir is part of the larger Hetch Hetchy Regional Water System that supplies drinking water to the City of San Francisco and irrigation water to the Central Valley. Lake Eleanor was created in 1918 and the water is used primarily for hydroelectric power. Cascades Dam, located on the Merced River downstream of Yosemite Valley since 1918, was recently removed and the river corridor restored. Numerous small dams and diversion are located throughout the park; most of these are associated with the High Sierra Camps.

The park also has numerous wells for drinking water sources. Most of the larger wells are located in the El Portal, Yosemite Valley, Crane Flat, White Wolf, Wawona, and Tuolumne Meadows areas. There are additional research and monitoring wells located throughout the park, many associated with restoration projects.

Figure 6: Lakes, rivers, and streams in Yosemite National Park.



HYDROLOGIC AND WATER QUALITY DATASETS

The Water Resources Division of the National Park Service conducted a search for existing water resources data in and near Yosemite National Park during the 1990s. The results are summarized in the Baseline Water Quality Data Inventory and Analysis report (National Park Service 1994). Twenty-four gaging stations were documented, with 18 inside the park boundary. NPS-WRD retrieved 21,651 water quality records that date from 1967-1993. Water quality records exist for the 14 Inventory and Monitoring Level 1 parameters.

Historic flow data are available from 39 gaging stations in or near the park. Currently, Yosemite has 48 active gaging stations with periods of record ranging from one to 96 years. Thirty-five of these stations were installed in the last four years (Appendix 2).

The USGS-WRD queried Legacy and Modernized STORET and NWIS as part of the water quality database project. After the data were compared for duplicates and checked for data quality, 3,692 records from Legacy STORET and 40,107 records from NWIS were imported to the main water quality database. There were zero records in Modernized STORET. Additional water quality datasets identified by the USGS and park staff include the US Geological Survey's Alpine Hydro Research Group data and UC Santa Barbara's seven lakes study.

WATER RESOURCES MONITORING

Numerous water quantity and water quality studies have been conducted in Yosemite National Park. The literature search captured 242 references which included 64 journal publications. I identified 18 sites with long-term streamflow records and four sites with long-term water quality records that may be of particular value to vital signs monitoring (Table 5).

Table 5: Long-term monitoring sites in Yosemite

Site Name	Period of Record	Water Quality	Flow
Big Creek Diversion nr Fish Camp	1969-present		x
Eleanor Cr nr Hetch Hetchy	1909-present		x
Falls Cr nr Hetch Hetchy	1915-1983		x
Hetch Hetchy Reservoir	1950s-present	x	
Lake Eleanor diversion tunnel	1997-present		x
Lk Eleantor Div to Cherry Lk nr Hetch Hetchy	1996-present		x
M Tuolumne River a Oakland Rec Camp	1916-2002		x
Merced R a Happy Isles Bridge nr Yosemite	1915-present		x
Merced R a Pohono Bridge nr Yosemite	1916-present		x
Merced River at Happy Isles	1967-present	x	
Merced River at Happy Isles	1915-present		x
Merced River nr Briceburg	1966-1984	x	
Merced River nr Briceburg	1965-1974,1999-present		x
SF Merced R a Wawona	1955-1975		x
SF Merced R nr El Portal	1950-1975		x
SF Tuolumne R nr Oakland Rec Camp	1923-2002		x
Smoky Jack Cr trib nr Yosemite Village	1963-present		x
Tenaya Cr nr Yosemite Village	1912-1958		x
Tuolumne R ab Early Intake nr Mather	1943-present		x
Tuolumne R bl early intake nr Mather	1966-2004		x
Tuolumne R nr Hetch Hetchy	1910-2004		x
Tuolumne River a Tuolumne Meadows	1973-1986	x	

The site with the longest period of water quality monitoring (1967-present) in the Sierra Nevada Network is the Merced River at Happy Isles, located in upper Yosemite Valley. Happy Isles is maintained by the US Geological Survey as part of the Hydrologic Benchmark Network. Recently, the USGS installed a chemical analyzer that records continuous nitrate plus nitrite concentrations (Peterson et al. 2005). The Happy Isles watershed area is 46,900 ha and the elevation ranges from 1,224 to 3,997 m. Like most Sierra streams, stream water at Happy Isles is dilute with a low buffering capacity; sp. conductance ranges from 3.0 to 65 uS/cm and alkalinity ranges from 20 to 360 meq/L (Mast and Clow 2000). Mast and Clow (2000) analyzed Happy Isles data set for long-term trends using water quality data from 1968-1995 (*refer to Trend Analyses section, below*). In addition to long-term monitoring data, there have been numerous additional research studies associated with Happy Isles (Hoffman et al. 1976, Clow et al. 1996, Brown and Short 1999).

The San Francisco Public Utilities Commision (SFPUC) has collected monthly surface water samples from Hetch Hetchy Reservoir since the 1950s. Currently the reservoir is sampled for alkalinity, hardness, pH, turbidity, temperature, specific conductance, chloride, and coliform bacteria (total and fecal). Limnology profiles are collected approximately once per month near O'Shaughnessy Dam. On occasion, SFPUC conducts additional sampling in the upper watershed. Water quality data are summarized in Sanitary Surveys approximately every five years and annually in Sanitary Survey Update Reports. Results indicate that water quality in Hetch Hetchy is of high quality and in full compliance with state and federal standards (San Francisco Water Team and CH2M HILL Inc. 1995, San Francisco Public Utilities Commission 1999).

The California Water Resources Control Board collected water quality data from 1973 to 1986 on the Tuolumne River near Tuolumne Meadows and from 1966 through 1989 on the Merced River near Briceburg.

The Yosemite Facilities Management Division monitors water quality for drinking water sources and wastewater discharge effluent. Detailed source location data are not widely published for security reasons; however, more information can be obtained from this division. In general, front country drinking water sources are monitored for total coliform, escherichia coli (most probable number/100ml), general minerals, general physical and inorganic chemical parameters. Monitoring frequency is dependent on the classification of the water system and the source (National Park Service 1999).

A Yosemite hydroclimate network was developed as an inter-agency effort over the last four years to further our understanding of meteorological, hydrological, and biogeochemical processes (DiLeo et al. 2003). Thirty-five new gaging stations were installed in the upper Merced and Tuolumne watersheds along with numerous water quality sampling locations.

The National Park Service monitors water quality (2004-present) as part of the Visitor Experience and Resource Protection Program (VERP) (Yosemite National Park 2004). Water quality is one of eleven indicators used to monitor the impacts of visitor use along the Merced Wild and Scenic River corridor. Parameters include fecal coliform, total nitrogen, total phosphorus, and petroleum hydrocarbons.

CURRENT RESEARCH PROJECTS

The US Geological Survey-Water Resources Division is investigating the sensitivity of high-elevation lakes to nitrogen deposition. Aspects of this project will specifically provide I&M with information that will help with indicator selection and sample design/protocol development.

Colorado State University is investigating the hydrological and ecological effects of groundwater pumping on water levels, fen carbon budget, and vegetation in Doghouse Meadow at Crane Flat (Cooper et al. 2005).

Texas A&M University and the U. S. Geological Survey are investigating the effects of pesticides on Pacific treefrog tadpoles along a north-south transect in the Sierra Nevada. Researchers trans-located tadpoles, placing them in chambers among sites located in Sequoia, Yosemite and Lassen National Parks (Sparling and Cowman 2003).

Portland State University is inventorying and mapping glaciers in Sequoia and Kings Canyon, Yosemite and the surrounding national forests (Basagic in progress). Information from this study will help managers understand how climate affects hydrologic processes in the Sierra Nevada.

University of California, Davis is investigating the prevalence and concentration of coliform bacteria in Sierra Nevada wilderness area lakes and streams. Researchers will collect water samples from over 120 lakes and streams, including waterbodies in Yosemite National Park (Derlet 2004).

LOCAL WATER RESOURCE ISSUES

In the Baseline Water Quality Report, water quality data were compared to EPA water quality criteria and instantaneous concentration values selected by the Water Resources Division (National Park Service 1994). Alkalinity exceeded the criteria (100% exceeding) more than any other constituent. Concentrations were below the threshold (200 ueq/l) used by the NPS Air Resources Division to determine potential sensitivity to acid deposition. The following constituents were found to exceed criteria for freshwater aquatic life: dissolved oxygen (2%), pH (26%), cyanide (13%), cadmium (50%), copper (6%), lead (46%), selenium (5%), mercury (5%), and zinc (5%). The following constituents exceeded EPA drinking water criteria: nitrite (4%), nitrate (3%), cadmium (50%), lead (86%), and mercury (8%). From data in the Baseline Water Quality Reports, NPS-WRD determined surface waters to be of good quality, with indications of some impact from human activities. Potential sources identified in the report are road networks, parking lots, bridges, campsites, fuel storage facilities, and wastewater discharges. Additionally, lower pH levels, which may be natural or anthropogenic, may mobilize trace elements in the larger rivers.

Groundwater pumping from wells located in Doghouse meadow and potentially other park fens are changing the soil and vegetation type in sections of these meadows. Fens require nearly year round saturation to maintain the peat soils; lowering of the water table will oxidize soil. Peat soils accumulate at an approximate rate of 20 cm/1000 yrs.

Altered hydrology (from roads and other infrastructure) and subsequent conifer encroachment is an issue in Tuolumne and Dana meadows. Conifer encroachment has also been observed on a larger scale, throughout the Sierra; this pattern is likely attributed to climatic forces.

Development in Yosemite Valley has altered the natural hydrologic processes in the Merced River. Areas of specific concern are the Sugar Pine, Stoneman, and Ahwahnee bridges, which are diverting flow and creating alternate river channels (National Park Service 2000).

Yosemite National Park receives over 3, 350, 000 visitor's per year, with the highest visitation concentrated during the summer months in Yosemite Valley. As a result, visitor use impacts are of high concern. These include increased inputs of nutrients, pathogens, metals, and pharmaceuticals, stream bottom litter, and water withdrawals. Stream bank degradation and disruption of natural sediment regimes are issues, especially along the Merced River corridor in Yosemite Valley.

BROAD-SCALE SPATIAL SURVEYS

There are several broad spatial studies that span Sierra Nevada parks and are of value to the vital signs monitoring program. These include the Western Lake Survey (Blick et al. 1987a, Clow et al. 2003), Amphibian and High Elevation Lakes Survey (Knapp et al. 2003), Comparative Analyses of High-Altitude Lakes and Catchments in the Sierra Nevada: Susceptibility to Acidification (Melack et al. 1998b), Distribution of Aquatic Animals Relative to Naturally Acidic Waters in the Sierra Nevada (Bradford et al. 1994).

The Western Lake Survey, conducted in 1985 by the EPA with cooperating agencies, was a one-time regional sampling of high elevation lakes in the mountainous west. The primary objectives were to determine the percentage and location of lakes that are acidic, determine the percentage and location of lakes that have low acid neutralizing capacity, determine the chemical characteristics of lake populations, and provide baseline data for future studies. Seven hundred and nineteen lakes, representing a target population of 10,393, were sampled throughout the west, including Yosemite, Sequoia and Kings Canyon and the upper Middle Fork of the San Joaquin above Devils Postpile. Clow et al. (2002) resurveyed a subset of these lakes (n=69) located in seven National Parks (Lassan, Yosemite, Sequoia, Kings Canyon, Grand Teton, Yellowstone, and Glacier). Results from both years indicate that lakes in the Sierra Nevada are some of the most dilute in the western US (Blick et al. 1987b, Eilers et al. 1989, Clow et al. 2002).

Berg et al. (2005) used the lake survey data to develop a screening procedure of Wilderness lakes to identify a subset of acid sensitive (i.e. low ANC) lakes for long-term monitoring. This model was applied to lakes in Sierra Nevada Wilderness areas by the Pacific Southwest Region, USDA Forest Service Air Resources Program to select long-term monitoring sites as part of the Sierra Nevada Forest Plan Amendment. This program has resulted in several protocols and reports specific to long-term lake monitoring in USFS lands adjacent to the Sierra Nevada Network (Berg and Grant 2004b, a, Berg 2005).

Researchers from UC Santa Barbara measured atmospheric deposition and surface-water chemistry in eight alpine and subalpine watersheds in the Sierra Nevada as part of the Comparative Analyses of High-Altitude Lakes and Catchments in the Sierra Nevada study (Melack et al. 1998a). The study watersheds span the Sierra Nevada and include sites in or near Lassen, Yosemite, and Sequoia. The purpose of the study was to assess the annual and long-term susceptibility of the Sierra Nevada lakes to acid deposition. The report includes spatial and temporal analyses of solutes during snowmelt runoff, volume-weighted mean chemistry, water balances, and solute mass balances for the seven watersheds. General patterns of surface water chemistry were detected; however, there was considerable variability between watersheds. The quantity and timing of snowmelt affected the temporal variability (annual and inter-annual) of water chemistry.

TIME SERIES PLOTS AND TREND ANALYSES

Four streams with long-term water quality records were identified for trend analyses using the Seasonal Kendall test. Three of the sites are located along an elevational gradient in the Middle Fork of the Kaweah in Sequoia National Park. These sites are Chamise Creek (750m) in the chaparral vegetation zone, Log Creek (2067m), both in the mixed conifer zone, and Emerald Lake Outflow (2807m) in the subalpine zone. The National Park Service, UC Santa Barbara, and US Geological Survey-Biological Resources Division have monitored these sites since the early 1980s. The fourth site is the Merced River at Happy Isles, which is located in the upper reaches of Yosemite Valley. Happy Isles is Hydrologic Benchmark Network since, maintained by the US Geological Survey-Water Resources Division since 1964.

Temporal analyses for Happy Isles were previously conducted for the period of 1968-1995. Using the seasonal Kendall test for trend, Mast and Clow (2000) detected statistically significant trends (α = .01) for pH and sulfate concentrations. They attributed the increasing trend in pH to inconsistencies between instruments or personnel through time as opposed to environmental factors. The decrease in sulfate was partially explained by variations in streamflow; however, interpretation was complicated by coinciding changes in analytical methods during the study period.

Long-term trends were analyzed in previous studies (Melack et al. 1998a, Clow et al. 2003) for Emerald Lake outflow. The analyses were computed again as part of this report to capture additional solutes and a longer time period and to better compare Emerald to Log and Chamise Creeks. One of the objectives of this report is to bring together these long-term data sets to assist the I&M program in developing the long-term monitoring plan. Trend test results and time series plots are presented together with some limited discussion. However, staff also should refer to previous publications and reports for in depth analyses and discussions on the hydrology and water chemistry of the individual watersheds.

Trend analyses for Chamise, Log, and Emerald were performed on raw and flow-adjusted concentrations (Table 6). Seasons were selected based on patterns in hydrology and solute concentrations. Log and Emerald, both snow-dominated watersheds, had similar seasonal patterns. Four seasons were selected for Log and Emerald: October-December, January-April, May-July, and August-September. Chamise Creek flows only during large storm events from fall to spring; chemistry data are not existent for the months of July-October. As a result, only three seasons were selected for Chamise: November-December, January-April, and May-June. Analyses were not computed for ammonium in Chamise, Log, or Emerald and nitrate in Chamise and Log. These data sets contained a high percentage (between 32% and 92%) of concentrations below detection levels.

Downward trends were detected for ANC in raw (p=.015) and flow-adjusted (p=.043) concentrations in Emerald outflow (Table 6 and Figure 7). Previous analyses of Emerald outflow data that covered the period of 1983-1994 did not detect long-term trends in ANC (Melack et al. 1998a). Differences may be attributed to a longer time period in our analyses or it may be attributed to differences in methodology (Melack et al. analyzed volume-weighted means using time series plots). In addition, the detected trends using the seasonal Kendall test were not very strong. Long-term trends in ANC were not detected for Log and Chamise.

Consistent with results from Clow et al. (2003), downward trends were detected for raw (p=.021) and flow-adjusted (p=.027) sulfate concentrations in Emerald outflow (Table 6 and Figure 7). Results are consistent with decreases in sulfate concentrations observed in the Western lakes survey follow-up, declining sulfate deposition, and declining sulfur dioxide emissions (Clow et al. 2002, Clow et al. 2003). A downward trend was detected in Log Creek for raw sulfate concentrations (p=0.050). A trend was not detected for flow-adjusted concentrations, suggesting that precipitation patterns may partially explain the sulfate decline. Trends were not detected in Chamise.

A weak, but decreasing trend in raw calcium concentrations was detected for Emerald (p=.046). Calcium trends were not detected in Log or Chamise (Table 6 and Figure 9). Trends were not detected at any of the sites for pH, specific conductance, temperature, nitrate, magnesium, sodium, potassium, and chloride (Table 6 and Figures 8-11). A decreasing trend in nitrate concentrations has been observed in Emerald outflow and Log Creek (Williams and Melack 1997a, Melack et al. 1998a). Again, differences are likely explained by time periods and methodologies and the changes are small.

Table 6: Seasonal Kendall test results for Chamise Creek, Log Creek and Emerald Lake outflow. P-values are bolded where a trend was detected (α = 0.05).

		Raw Concentrations			Flow-adjusted Concentrations		
		n	**p-value**	**trend**	**n**	**p-value**	**trend**
pH	Chamise	22	0.063	none	21	**0.013**	**up**
	Log	60	0.090	none	60	0.076	none
	Emerald	57	0.762	none	57	0.558	none
Sp. Cond	Chamise	22	0.568	none	21	0.960	none
	Log	60	0.305	none	60	0.173	none
	Emerald	57	0.812	none	57	0.629	none
Temp	Chamise	19	0.903	none	-	-	-
	Log	56	0.170	none	-	-	-
	Emerald	53	0.121	none	-	-	-
ANC	Chamise	22	0.455	none	21	0.706	none
	Log	60	0.248	none	60	0.869	none
	Emerald	57	**0.015**	**down**	57	**0.043**	**down**
NH4	Chamise	-	-	-	-	-	-
	Log	-	-	-	-	-	-
	Emerald	-	-	-	-	-	-
NO3	Chamise	-	-	-	-	-	-
	Log	-	-	-	-	-	-
	Emerald	57	0.720	none	57	0.585	none
Ca	Chamise	22	0.822	none	21	1.000	none
	Log	60	0.243	none	60	0.687	none
	Emerald	57	**0.046**	**down**	57	0.065	none
Mg	Chamise	22	0.834	none	21	0.876	none
	Log	60	0.685	none	60	0.209	none
	Emerald	57	0.230	none	57	0.299	none
Na	Chamise	22	0.916	none	21	0.626	none
	Log	60	0.844	none	60	0.053	none
	Emerald	57	0.526	none	57	1.000	none
K	Chamise	22	0.665	none	21	0.624	none
	Log	60	0.119	none	60	0.214	none
	Emerald	57	0.068	none	57	0.092	none
SO4	Chamise	22	0.230	none	21	0.236	none
	Log	60	**0.050**	**down**	60	0.082	none
	Emerald	57	**0.021**	**down**	57	**0.027**	**down**
Cl	Chamise	22	0.076	none	21	0.073	none
	Log	60	0.108	none	60	0.241	none
	Emerald	57	0.060	none	57	0.084	none

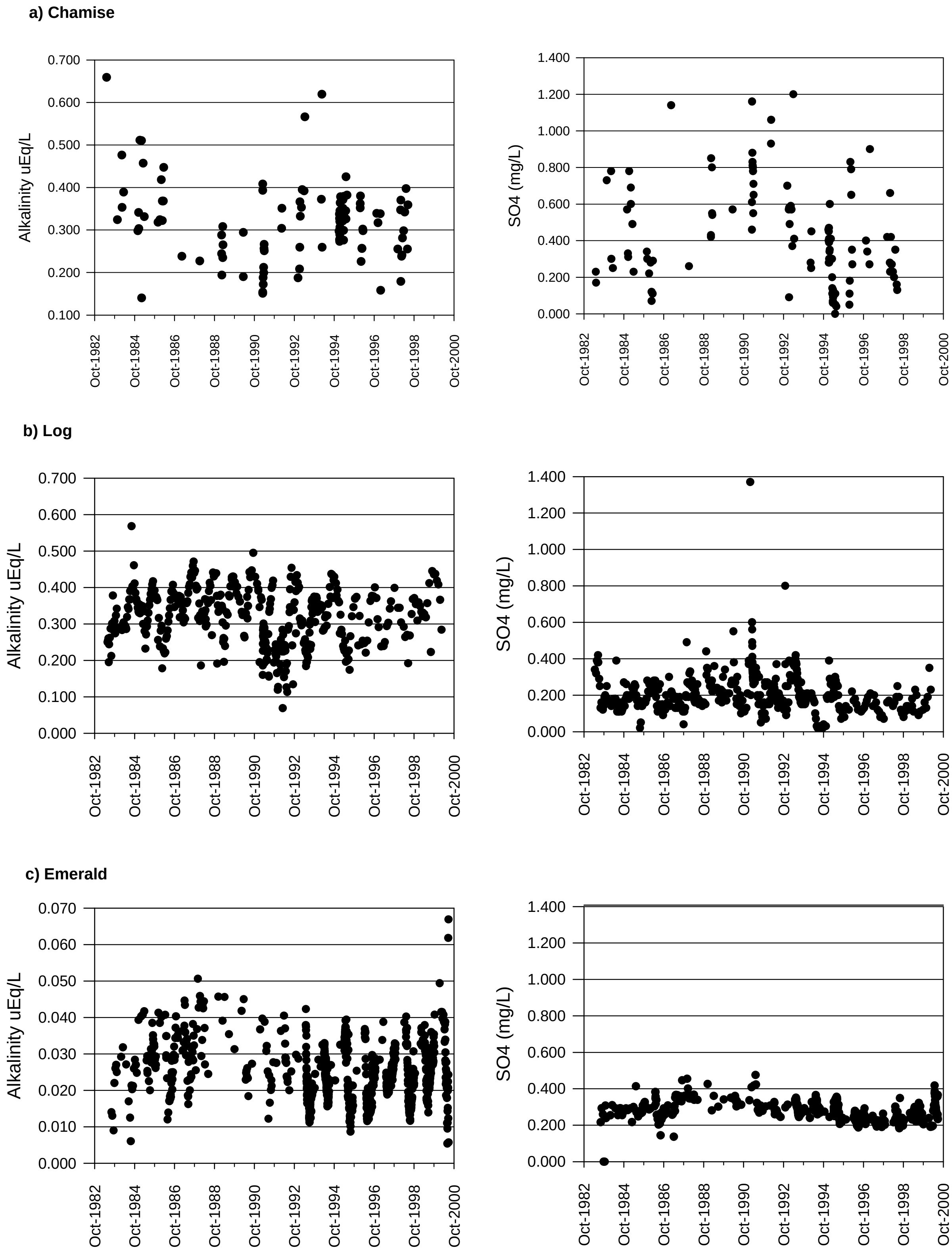


Figure 7: ANC and sulfate time series plots for a) Chamise, b) Log, and, c) Emerald.

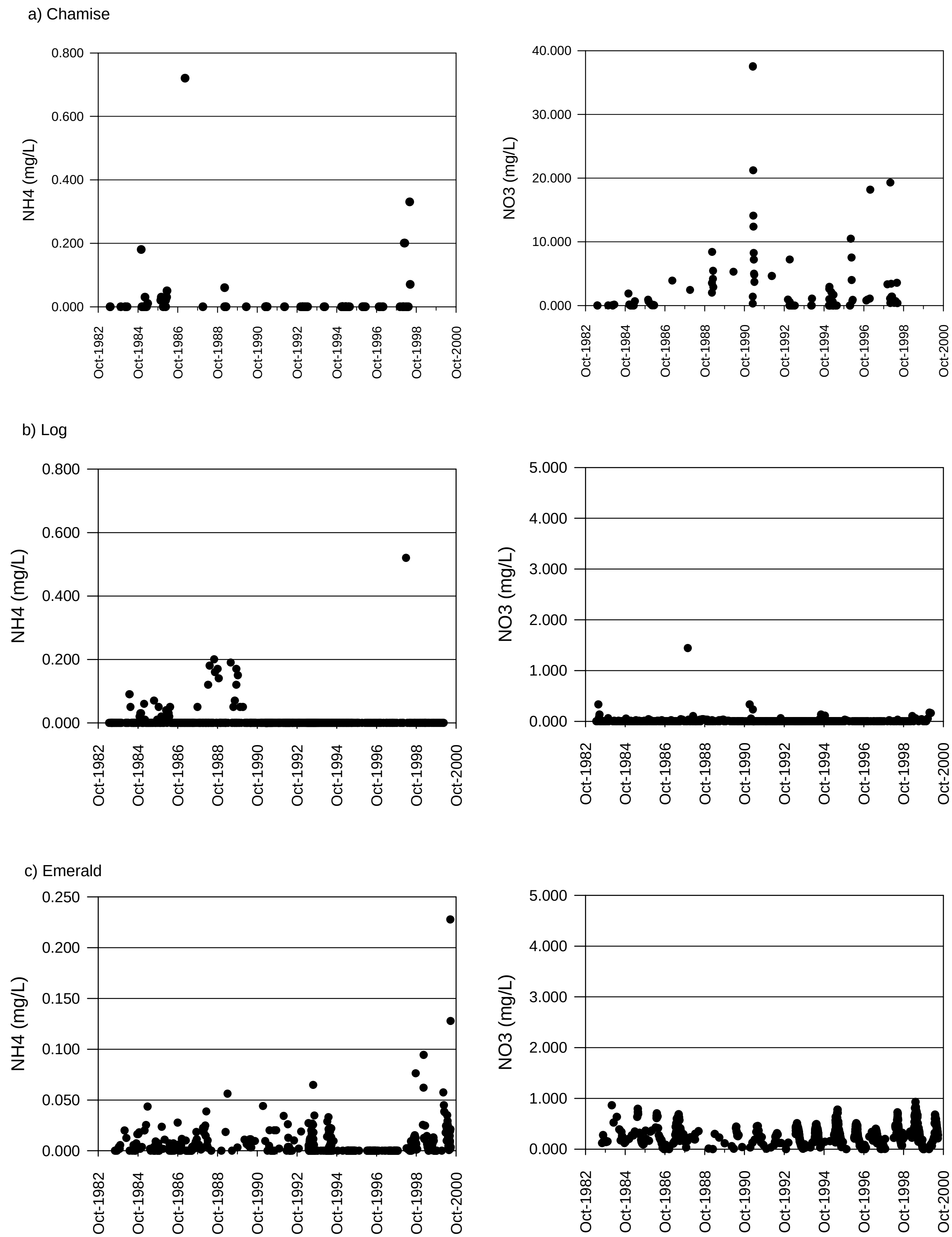


Figure 8: Ammonium and nitrate time series plots for a) Chamise, b) Log, and c) Emerald.

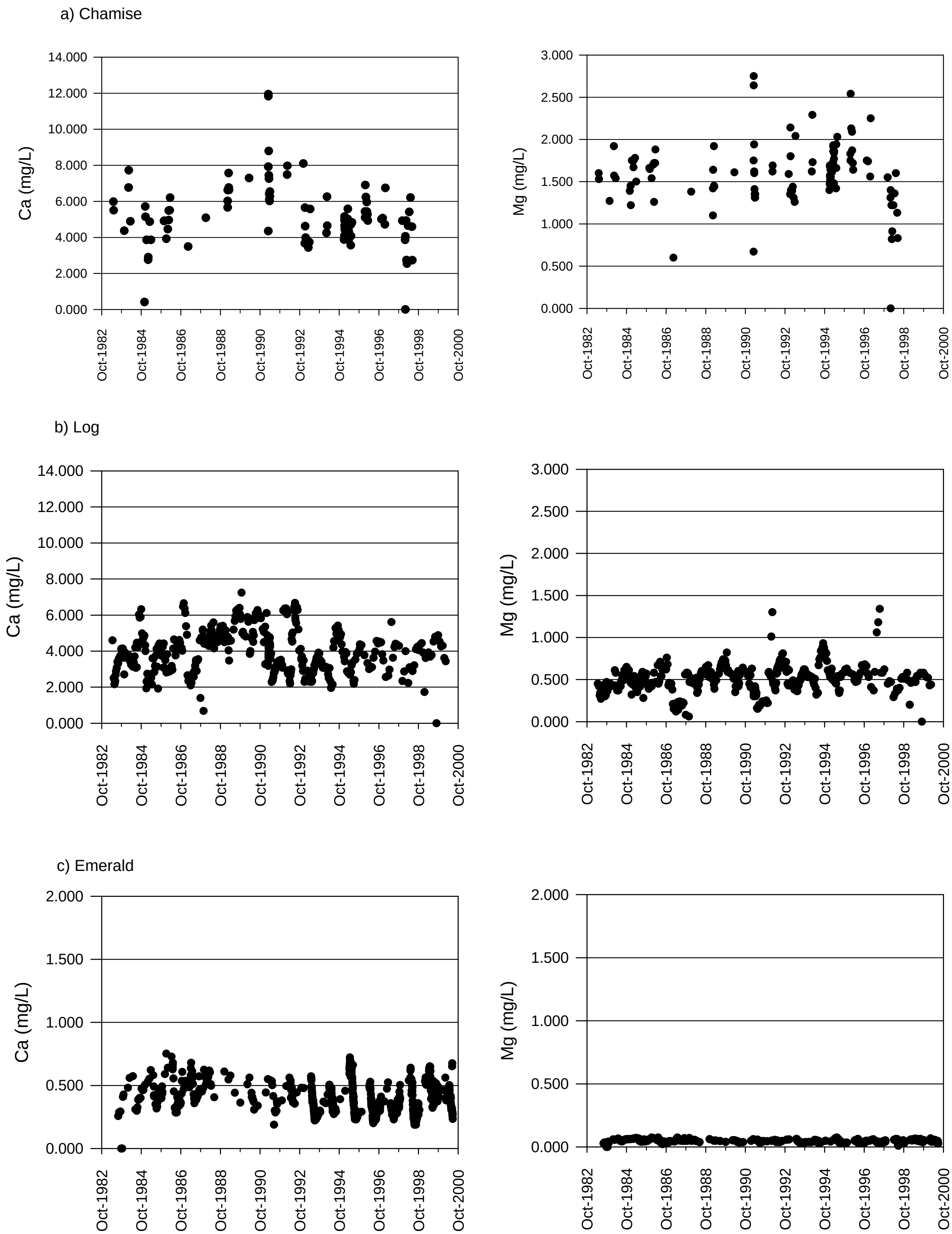


Figure 9: Calcium and magnesium time series plots for a) Chamise, b) Log, and c) Emerald.

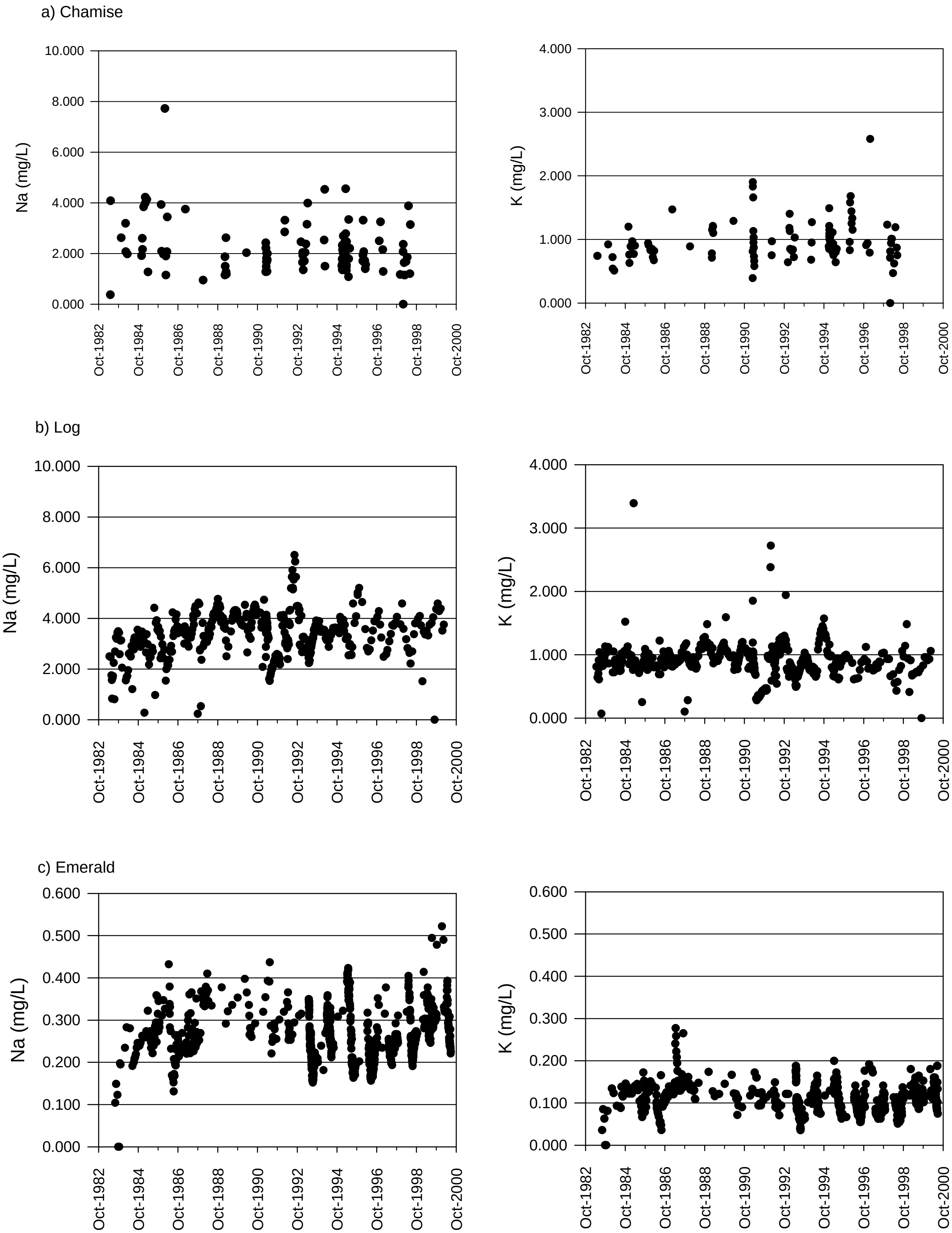


Figure 10: Sodium and potassium time series plots for a) Chamise, b) Log, and c) Emerald.

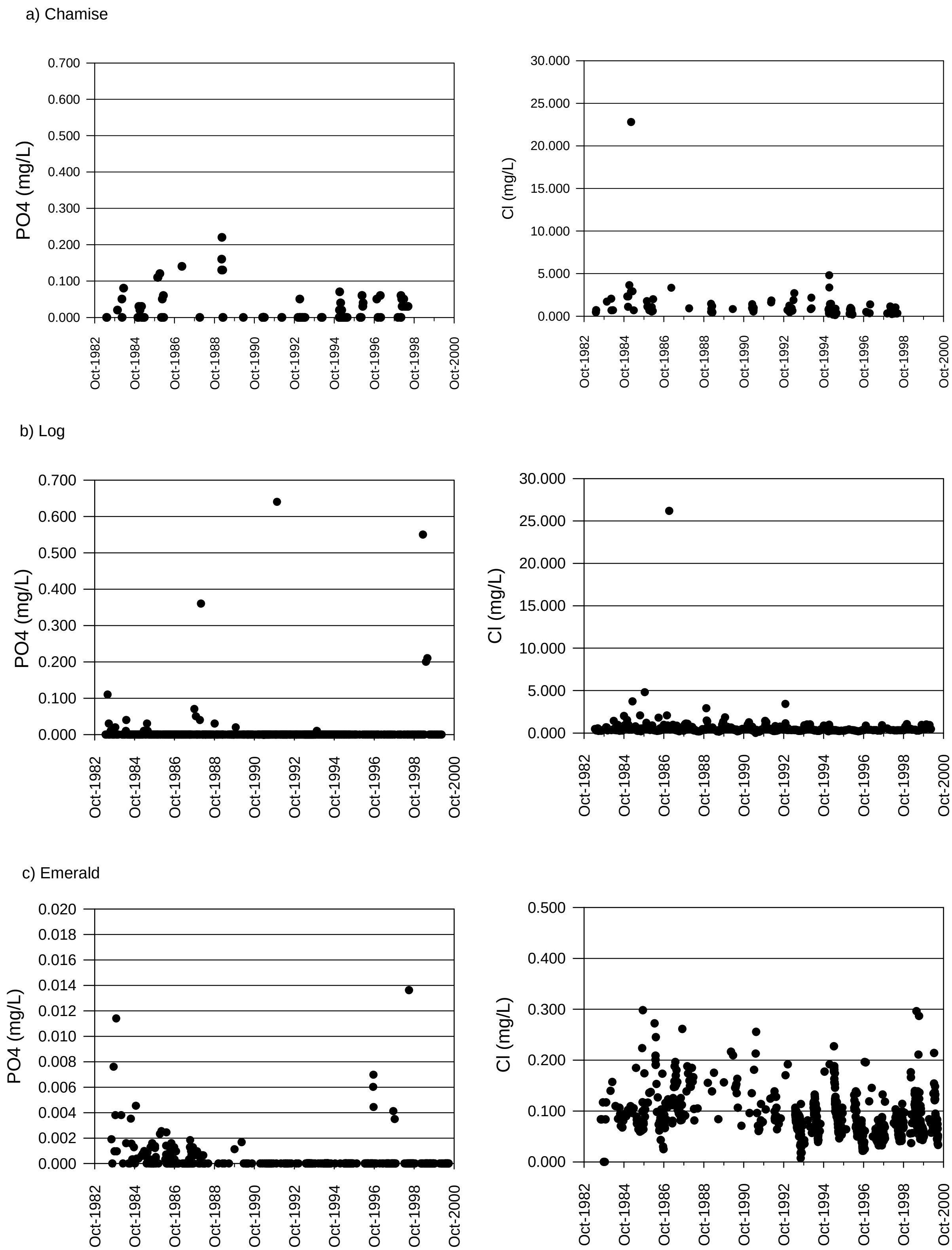


Figure 11: Phosphate and chloride time series plots for a) Chamise, b) Log, and c) Emerald.

SUMMARY

There are a substantial amount of water resource research and monitoring projects in the Sierra Nevada Network parks that the I&M program can use as a baseline for developing the Vital Signs monitoring plan. In summary, over 560 references were captured in the literature search, 802 water quality sites and 310,639 water quality records identified and uploaded to the water quality geodatabase, and 34 long-term monitoring sites identified. Most of the existing information is concentrated in the Merced, Kaweah, and Tuolumne watersheds. The watersheds with the least amount of baseline data are the Kings and Kern.

Time series plots and trend analyses data were presented for sites with long-term water quality monitoring data (Emerald outflow, Log Creek, and Chamise Creek and Merced River at Happy Isles). These sites have been well studied over the last 20-50 years; as a result, there are numerous publications investigating spatial and temporal trends specific to SIEN parks (refer to *SIEN Water* library). This information will provide network staff with a greater understanding of the temporal and spatial patterns and variability of water chemistry in SIEN parks. The new water geodatabase will enable to staff to further investigate spatial variability and patterns using existing water quality data.

ACKNOWLEDGEMENTS

The Sequoia and Kings Canyon History section was written and map templates were developed by Curtis Stumpf, Student Conservation Associate.

LITERATURE CITED

Baas, J., F. D. Westerdahl, and R. L. Perrine. 1976. Non-point source water quality monitoring, Inyo National Forest, 1975. Progress Report Contribution No. 156, University of California, Davis

University of California, Los Angeles, Los Angeles.

Berg, N. H. 2005. Water quality review: Sierra Nevada 2004 lake monitoring. Draft PSW Research Station, USDA Forest Service.

Berg, N. H., A. Gallegos, T. Dell, J. Frazier, T. Procter, J. Sickman, S. Grant, T. Blett, and M. Arbaugh. 2005. A screening procedure for identifying acid-sensitive lakes from catchment characteristics. Environmental Monitoring and Assessment **105**:285-307.

Berg, N. H., and S. Grant. 2004a. Project Lakes: Long-term water quality monitoring and zooplankton data collection protocol. USDA Forest Service, Pacific Southwest Region.

Berg, N. H., and S. Grant. 2004b. Project Lakes: Synoptic water quality data collection protocol. Final Draft USDA Forest Service, Pacific Southwest Region.

Blick, D. J., D. F. Brakke, M. S. DeHaan, J. M. Eilers, P. Kanciruk, P. E. Kellar, D. H. Landers, R. A. McCord, W. S. Overton, and M. E. Silverstein. 1987a. Western Lake Survey, Phase I, Characteristics of lakes in the Western United States. EPA-600/3-86/054b, U. S. Environmental Protection Agency, Office of acid deposition, environmental monitoring and quality assurance, Washington, D.C.

Blick, D. J., D. F. Grakke, M. S. DeHaan, J. M. Eilers, P. Kanciruk, P. E. Kellar, D. H. Landers, R. A. McCord, W. S. Overton, and M. E. Silverstein. 1987b. Western Lake Survey, Phase I, Characteristics of lakes in the Western United States. U.S. Environmental Protection Agency, Office of acid deposition, environmental monitoring and quality assurance, Washington, D.C.

Bradford, D. F., S. D. Cooper, and A. D. Brown. 1994. Distribution of aquatic animals relative to naturally acidic waters in the Sierra Nevada. Final Report for Contract No. A132-173, California Air Resources Board, Sacramento, CA.

Brown, L., and T. Short. 1999. Biological, Habitat, and Water Quality Conditions in the Upper Merced River Drainage, Yosemite National Park, California, 1993-1996. USGS/WRI- 99-4088, U. S. Geological Survey and National Park Service, Sacramento, CA.

Cahill, T. A., J. J. Carroll, D. Campbell, and T. E. Gill. 1996. Air Quality. Pages 1227-1260 *In* Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options, Davis, CA.

California Regional Water Quality Control Board Central Valley Region. 1995. Water Quality Control Plan for the Tulare Lake Basin, Second Edition - 1995.

California Regional Water Quality Control Board Central Valley Region. 1998. The Water Quality Control Plan for the Sacramento River Basin and the San Joaquin River Basin. Sacramento, CA.

Caprio, A. C. 1999. Research, inventory and monitoring: Mineral King Risk Reduction Project. Annual Report 1998, Sequoia and Kings Canyon National Parks, Three Rivers.

Caprio, A. C. 2004. Personal communication. A. Heard, editor.

Caprio, A. C., and P. Lineback. 1997. Pre-twentieth century fire history of Sequoia and Kings Canyon National Park: A review and evaluation of our knowledge. Fire in California Ecosystems: Integrating Ecology, Prevention, and Management, San Diego, CA.

Chorover, J., P. M. Vitousek, D. A. Everson, A. M. Esperanza, and D. Turner. 1994. Solution chemistry profiles of mixed-conifer forests before and after fire. Biogeochemistry **26**:115-144.

Clow, D. W., M. A. Mast, and D. H. Campbell. 1996. Controls on surface water chemistry in the upper Merced River basin, Yosemite National Park, California. Hydrological Processes **10**:727-746.

Clow, D. W., J. O. Sickman, R. G. Striegl, D. P. Krabbenhoft, J. G. Elliott, M. Dornblaser, D. A. Roth, and D. H. Campbell. 2003. Changes in the chemistry of lakes and precipitation in high-elevation national parks in the western United States, 1985-1999. Water Resources Research **39**.

Clow, D. W., R. G. Striegl, M. Nanus, M. A. Mast, D. H. Campbell, and D. P. Krabbenhoft. 2002. Chemistry of selected high-elevation lakes in seven national parks in the western United States. Water Air and Soil Pollution **2**:139-164.

Cooper, D., E. C. Wolf, and R. Chimner. 2005. Hydrological and ecological analysis of the effects of groundwater pumping on water levels, fen carbon budget and vegetation, in Crane Flat, Yosemite National Park, California. Progress report Colorado State University, Fort Collins, CO.

Davidson, C., and H. B. Shaffer. 2002. Spatial tests of the pesticide drift, habitat destruction, UV-B, and climate change hypotheses for California amphibian declines. Conservation Biology **16**:1588-1601.

Derlet, R. W. 2004. Prevelance of coliform and other pathogenic bacteria in Sierra Nevada National Parks and Wilderness Area Lakes and Streams. Research Permit University of California, Davis.

Dettinger, M. D., D. R. Cayan, M. Meyer, and A. E. Jeton. 2004. Simulated hydrologic responses to climate variations and change in the Merced, Carson, and American River basins, Sierra Nevada, California, 1900-2099. Climatic Change **62**:283-317.

DiLeo, J., M. Butler, D. R. Cayan, D. W. Clow, M. D. Dettinger, F. Gehrke, S. Hager, J. D. Lundquist, G. McCurdy, D. Peterson, K. Redmond, L. Riddle, R. Smith, and J. W. van Wagtendonk. 2003. Notebook of Hydroclimatology - Sites/Activities. Yosemite National Park, El Portal.

Dilsaver, L. M., and W. C. Tweed. 1991. The Challenge of the Big Trees: A Resource History of Sequoia and Kings Canyon National Park. University of Arizona Press.

Eilers, J. M., D. F. Brakke, D. H. Landers, and W. S. Overton. 1989. Chemistry of wilderness lakes in the Western United States. Environmental Monitoring and Assessment **12**.

Environmental Protection Agency. 2003. STORET Water Quality Database. http://www.epa.gov/storet/ Date Accessed:

Fancy, S., and J. Gross. 2004. Monitoring Natural Resources in our National Parks. http://science.nature.nps.gov/im/monitor/index.htm Date Accessed: April.

Goldman, C. R., A. D. Jassby, and S. H. Hackley. 1993. Decadal, interannual and seasonal variability in enrichment bioassays at Lake Tahoe, California-Nevada, USA. Canadian Journal of Fisheries and Aquatic Sciences **50**:1489-1496.

Hauer, F. R., and C. N. Spencer. 1998. Phosphorus and nitrogen dynamics in streams associated with wildfire: a study of immediate and long-term effects. International Journal of Wildland Fire **8**:183-198.

Heard, A. M. 2005. Effects of landscape scale prescribed fire on hydrology and stream chemistry. MS. Coloradao State University, Fort Collins, CO.

Helvey, J. D. 1980. Effects of a north central Washington fire on runoff and sediment production. Water Resources Bulletin **16**:627-634.

Hirsch, R. A., and J. R. Slack. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research **20**:727-732.

Hoffman, R. J., A. E. Dong, and G. L. Keeter. 1976. Water-Quality Study of a Reach of the Merced River in Yosemite National Park and Vicinity, California--April 1973 Through September 1974. Open-file report 76-326, Geological Survey, Water Resources Div, Menlo Park, Calif.

Houghton, J. T., L. G. Miera Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell. 1996. Climate change 1995: the science of climate change. Cambridge University Press, Cambridge, UK.

Huber, N. K., and W. W. Eckhardt. 2002. The Story of Devils Postpile. Sequoia National History Association, Three Rivers.

Information Center for the Environment. 2003. Water quality standards inventory database: beneficial uses. http://www.ice.ucdavis.edu/wqsid/bu.asp Date Accessed: November.

Kattelmann, R. 1996. Hydrology and Water Resources. *In* Sierra Nevada Ecosystem Project, Davis, CA.

Knapp, R. A., K. R. Matthews, H. K. Preisler, and R. Jellison. 2003. Developing probabilistic models to predict amphibian site occupancy in a patchy landscape. Ecological Applications **13**:1069-1082.

Knowles, N., and D. R. Cayan. 2001. Global climate change: potential effects on the Sacramento/San Joaquin watershed and the San Francisco estuary. IEP Newsletter **14**:23-29.

LeNoir, J. S., L. L. McConnell, G. M. Fellers, T. M. Cahill, and J. N. Seiber. 1999. Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada Mountain Range, USA. Environmental Toxicology and Chemistry **18**:2715-2722.

Leydecker, A., J. O. Sickman, and J. M. Melack. 1999. Episodic lake acidification in the Sierra Nevada, California. Water Resources Research **35**:2793-2804.

Mac Donald, L. H., and J. D. Stednick. 2003. Forests and Water: A state-of-the-art review for Colorado. CWRRI Completion Report No. 196, Colorado State University, Fort Collins, CO.

Mast, M. A., and D. W. Clow. 2000. Environmental characteristics and water quality of Hydrologic Benchmark Network stations in the western United States. Circular Report U.S. Geologic Survey.

Meadows, R. 2004.

Melack, J., J. O. Sickman, A. Leydecker, and D. Marrett. 1998a. Comparative analyses of high-altitude lakes and catchments in the Sierra Nevada: susceptibility to acidification. Final report to the California Air Resources Board, Contract No. A032-188., Sacramento, CA.

Melack, J. M., J. O. Sickman, and A. Leydecker. 1998b. Comparative analyses of high-altitude lakes and catchments in the Sierra Nevada: Susceptibility to acidification. Final Report, California Air Resources Board Contract A032-188, Santa Barbara, CA.

Melack, J. M., J. O. Sickman, and J. Schimel. 2002. Microbial and hydrological controls of nitrogen losses from alpine and chaparral ecosystems during seasonal transitions-research proposal. Proposal University California, Santa Barbara, Santa Barbara, CA.

Moore, C. 2000. 1999 annual Sequoia watershed report. *In* 1999 annual fire report on research, monitoring and inventory. Sequoia and Kings Canyon National Parks, Three Rivers, CA.

National Atmospheric Deposition Program (NRSP-3)/National Trends Network. 2004. National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/ Date Accessed: April.

National Park Service. 1994. Baseline water quality data inventory and analysis -- Yosemite National Park. National Park Service, Water Resources Division, Fort Collins, CO.

National Park Service. 1998. Baseline Water Quality Data Inventory and Analysis- Devils Postpile National Monument. Technical Report NPS/NRWRD/NRTR-98/189, National Park Service, Water Resources Division, Fort Collins, CO.

National Park Service. 1999. Reference A: Reference Manual 83, Drinking Water.

National Park Service. 2000. Final Yosemite Valley Plan, Supplemental Environmental Impact Statement. National Park Service, Yosemite National Park.

National Park Service. 2002a. Devils Postpile National Monument Vital Signs Workshop Report.

National Park Service. 2002b. DRAFT: Sequoia and Kings Canyon National Parks Wild and Scenic River Plan and Study. Draft Management Plan Sequoia and Kings Canyon National Parks, Three Rivers, CA.

National Park Service. 2003a. 2002 Consumer Confidence Reports. National Park Service, Three Rivers, CA.

National Park Service. 2003b. Nature and Science: Devils Postpile National Monument, Water Resources. http://www.nps.gov/depo/depo_nr/water/water.htm Date Accessed: April.

National Park Service Air Resources Division. 2003. Western Airborne Contaminants Assessment Project. Fact Sheet National Park Service Air Resources Division,, Denver, CO.

National Park Service- Freshwater Workgroup Subcommittee. 2002. Recommendations for core water quality monitoring parameters and other key elements of the NPS Vital Signs program, water quality monitoring component. National Park Service, Fort Collins, CO.

National Park Service, W. R. D. 1997. Baseline Water Quality Data Inventory & Analysis -- Sequoia and Kings Canyon National Parks. Technical Report NPS/NRWRD/NRTR-97/121, National Park Service, Washington, D.C.

National Park Service-Water Resources Division. 2003. Draft: Surface water quality monitoring issues, overview and assessment. National Park Service-Water Resources Division,, Fort Collins, CO.

Peterson, D., R. Smith, S. Hager, J. Hicke, M. Dettinger, and K. Huber. 2005. River chemistry as a monitor of Yosemite Park mountain hydroclimates. EOS **86**:285-292.

Riggan, P. J., R. N. Lockwood, P. M. Jacks, and C. G. Colver. 1994. Effects of fire severity on nitrate mobilization in watersheds subject to chronic atmospheric deposition. Environ Sci Technol **28**:369-375.

Rowan, D. E., S. C. Parmenter, and W. W. Eckhardt. 1996. Fishery and riparian resources of Devils Postpile National Monument and surrounding waters. National Park Service.

San Francisco Public Utilities Commission. 1999. 1999 annual sanitary survey update report for the Hetch Hetchy water supply. San Francisco Public Utilities Commission, Water Quality Bureau, Engineering Section, San Francisco.

San Francisco Water Team, and CH2M HILL Inc. 1995. Final Sanitary Survey for the Hetch Hetchy Water Supply Project. San Francisco Water Team; CH2M HILL, Inc.

Schroeter, R. E., and J. M. Harrington. 1995. Benthic Macroinvertebrate Community Assessment of the Middle Fork San Joaquin River, Madera County, California. California Department of Fish and Game, Water Pollution Control Laboratory, Rancho Cordova, CA.

Schwarz, P. 2004. Re: Request for Water Quality Monitoring Information. A. Heard, editor., Three Rivers, CA.

Sequoia and Kings Canyon National Parks. 1999. Natural and Cultural Resources Management Plan. National Park Service, Three Rivers, CA.

Sequoia and Kings Canyon National Parks. 2002a. Ash Mountian Precipitation Data. 47050 Generals Highway, Three Rivers, CA 93271.

Sequoia and Kings Canyon National Parks. 2002b. lakeseki. Accessed:

Sickman, J. O., J. M. Melack, and D. W. Clow. 2003. Evidence for nutrient enrichment of high-elevation lakes in the Sierra Nevada, California. Limnology and Oceanography **48**:1885-1892.

Slack, J. R., D. L. Lorenz, and and others. 2003. USGS library for S-Plus for Windows -- Release 2.1. Open-File Report 03-357, U.S. Geological Survey.

SNEP. 1996. Sierra Nevada Ecosystem Project: Final Report to Congress- Summary. University of California, Davis, Davis, CA.

Sparling, D. W., and D. Cowman. 2003. Amphibians and Pesitcides in Pristine Areas. *In* G. Linder and et al., editors. Amphibian Decline: An Integrated Analysis of Multiple Stressor Effects. Society of Environmental Toxicology and Chemistry.

Sparling, D. W., G. M. Fellers, and L. L. McConnell. 2001. Pesticides and amphibian populations declines in California, USA. Environmental Toxicology and Chemistry **20**:1591-1595.

Spencer, C. N., K. O. Gabel, and F. R. Hauer. 2003. Wildfire effects on stream food webs and nutrient dynamics in Glacier National Park, USA. Forest Ecology and Management **178**:141-153.

State Water Resources Control Board. 2002. 2002 California 305(b) report. California Environmental Protection Agency State Water Resources Control Board.

Strong, D. 1996. From Pioneers to Preservationists: A Brief History of Sequoia and Kings Canyon National Parks. Sequoia Natural History Association.

Swetnam, T. W. 1993. Fire History and Climate-Change in Giant Sequoia Groves. Science **262**:885-889.

Tiedemann, A. R., J. D. Helvey, and T. D. Anderson. 1978. Stream chemistry and watershed nutrient economy following wildfire and fertilization in eastern Washington. Journal of Environmental Quality **7**:580-588.

U. S. Army Corps of Engineers. 2002. 1325 J Street, Sacramento CA 95814.

U. S. Geological Survey. 2000. Hydrologic Benchmark Network. http://water.usgs.gov/hbn/ Date Accessed: March.

U. S. Geological Survey. 2001. History of the National Uranium Resource Evaluation Hydrogeochemical and Stream Reconnaissance Program. http://pubs.usgs.gov/of/1997/ofr-97-0492/nurehist.htm Date Accessed: April, 2004.

U. S. Geological Survey. 2003. National Water Information System. http://nwis.waterdata.usgs.gov/ca/nwis/ Date Accessed:

U. S. Geological Survey - Biological Resources Division. 2000. Stream and Meteorology Sampling Protocol. U. S. Geological Survey - Biological Resources Division - Sequoia and Kings Canyon Field Station, Three Rivers, CA.

Werner, H. W. 2004. Personal Communication.

Williams, M. R., and J. M. Melack. 1997a. Atmospheric deposition, mass balances, and processes regulating streamwater solute concentrations in mixed-conifer catchments of the Sierra Nevada, California. Biogeochemistry **37**:111-144.

Williams, M. R., and J. M. Melack. 1997b. Effects of prescribed burning and drought on the solute chemistry of mixed-conifer forest streams of the Sierra Nevada, California. Biogeochemistry **39**:225-253.

Yosemite National Park. 2004. Visitor Experience and Resource Protection Program, 2004 annual report Merced River monitoring. National Park Service, El Portal, CA.

APPENDICES

Appendix 1: Diversions, wells, and impoundments in Devils Postpile National Monument (DEPO) and Sequoia and Kings Canyon National Parks (SEKI) (National Park Service 1997, National Park Service 1998, 2003a, Meadows 2004, Werner 2004).

Park	Location	Type	Purpose	Responsible Agency
DEPO	Devils Postpile Well	Well	Drinking Water	DEPO
SEKI	400' Well, Grant Grove	Well	Drinking Water	SEKI
	Alder Creek	Diversion	Drinking Water	SEKI
	Artesion Well, Grant Grove	Well	Drinking Water	SEKI
	Ash Mountain Well	Well	Drinking Water	SEKI
	Atwell Creek	Diversion	Drinking Water	SEKI
	Bear Paw	Diversion	Drinking Water	SEKI
	Buckeye Campground Well	Well	Drinking Water	SEKI
	Cabin Creek	Diversion	Drinking Water	SEKI
	Cold Springs	Diversion	Drinking Water	SEKI
	Coyote Creek	Diversion	Drinking Water	SEKI
	Crescent Creek	Diversion	Drinking Water	SEKI
	Crystal Lake	Impoundment	Power	SCE
	Eagle Lake	Impoundment	Power	SCE
	Hocket Meadow	Well	Drinking Water	SEKI
	Lower Franklin Lake	Impoundment	Power	SCE
	Marble Fork Kaweah near Potwisha	Diversion	Power	SEKI
	Merrit Springs	Diversion	Drinking Water	SEKI
	Middle Fork Kaweah nr Potwisha	Diversion	Power	SEKI
	Potwisha Campground Well	Well	Drinking Water	SEKI
	Redwood Meadow Spring	Diversion	Drinking Water	SEKI
	Roaring River	Diversion	Drinking Water	SEKI
	Rona Springs	Diversion	Drinking Water	SEKI
	Sheep Creek, Cedar Grove	Diversion	Drinking Water	SEKI
	Silliman Creek	Diversion	Drinking Water	SEKI
	Turkey Creek, Dorst	Diversion	Drinking Water	SEKI
	Un-named Creek nr Crystal Cave	Diversion	Drinking Water	SEKI
	Upper Monarch Lake	Impoundment	Power	SCE
	Wolverton Creek	Diversion	Drinking Water	SEKI
	Wolverton Meadow Well	Well	Drinking Water	SEKI

Appendix 2: Current and historic gaging stations in or near Devils Postpile National Monument (DEPO), Sequoia and Kings Canyon National Parks (SEKI), and Yosemite National Park (YOSE).

Station Name	Period of Record	Station ID	In Park?	Data Type	Data Location	Drainage Area (ha)	Eleva. (m)	Lat	Long
DEPO									
Middle Fork San Joaquin- in DEPO	2004-present		Yes	Raw	Scripps				
Middle Fork San Joaquin- at Miller Crossing	1921-1991	11226500	No	DM, PQ	NWIS Web	47,600	2110	37.51049694	-119.1973475
SEKI									
Chamise Creek	1985-2000, 2002-present	1	Yes	DM, Raw	SEKI	4	750	36.51333565	-118.809242
Log Creek	1983-2000, 2003-present	4	Yes	DM, Raw	SEKI	49	2067	36.56108429	-118.739121
Tharps Creek	1983-2000, 2003-present	6	Yes	DM, Raw	SEKI	13	2067	36.56225693	-118.7398502
Trauger's Creek	1996-present	22	Yes	DM, Raw	SEKI	104	1400	36.44	-118.73
Deadwood Creek	1996-present	28	Yes	DM, Raw	SEKI	100	2000	36.47	-118.66
Emerald Outflow	1983-present	8	Yes	DT	UCSB/SEKI	120	2807	36.59694444	-117.3252778
Marble Fork Kaweah above falls	1992-present	11206800	Yes	DT	UCSB/SEKI	1,900	2621	36.60611111	-117.3169444
Topaz Outflow	1986-present	363730118381701	Yes	DT	UCSB/SEKI	178	3218	36.625	-117.3636111
Pear Lake	1984-1994	363612118404001	Yes	DT	UCSB/SEKI	136	2904	36.6	-118.67
Middle Fork Kaweah - at Potwisha*	1949-present	11206501	Yes	DM, PQ	NWIS Web	26,400		36.5132786	-118.7917647
Marble Fork Kaweah- at Potwisha*	1950-present	11208001	Yes	DM, PQ	NWIS Web	13,300		36.51883444	-118.8017653
East Fork Kaweah - nr 3 Rivers*	1952-present	11208731	No	DM, PQ	NWIS Web	22,200	790	36.4516125	-118.7892639
Kaweah River nr Hammond*	1993-present	11208601	No	DM, PQ	NWIS Web	88,500	421	36.4860572	-118.8367656
South Fork Kaweah- nr Three Rivers	1911-1924	11210000	No	DM, PQ	NWIS Web	17,200	490	36.3749472	-118.8564869
South Fork Kings- nr Cedar Grove	1950-1957	11212500	Yes	DM, PQ	NWIS Web	10,500		36.8068872	-118.7495458

Station Name	Period of Record	Station ID	In Park?	Data Type	Data Location	Drainage Area (ha)	Eleva. (m)	Lat	Long
Kaweah R- nr Three Rivers	1903-1961	11210500	No	DM, PQ	NWIS Web	134,000	186	36.406615	-118.9542678
East Fork Kaweah- at Seq Natl P Bndry	1968-1971	11208625	Yes	DM, PQ	NWIS Web	6,130		36.4582761	-118.6539833
Middle Fork Kaweah Trib- near Mather	1967-1973	11208500	Yes	DM, PQ	NWIS Web	490		36.49300167	-118.8259319
East Fork Kaweah- Bl Mosquito Cr	1968-1973	11208620	Yes	DM, PQ	NWIS Web	4,100		36.4513308	-118.6187047
Monarch Creek	1968-1973	11208610	Yes	DM, PQ	NWIS Web	490		36.45244139	-118.5945378
North Fork Kaweah- at Kaweah	1910-1981	11209500	No	DM, PQ	NWIS Web	33,400	313	36.49022528	-118.9209344
Kaweah R- at Three Rivers	1958-1990	11209900	No	DM, PQ	NWIS Web	108,000	247	36.44383639	-118.9034333
Sf Kaweah R A Three Rivers Ca	1958-1990	11210100	No	DM, PQ	NWIS Web	22,400	246	36.41661444	-118.9142667
Dorst Creek- nr Kaweah Camp	1960-1973	11209000	Yes	PQ	NWIS Web	1,580		36.6457783	-118.8051008
Atwell Creek	1971-1977	11208630	Yes	PQ	NWIS Web	170		36.46577667	-118.6759283
YOSE									
Bell Creek nr Pinecrest	1963-1973	11283200		DM, PQ	NWISWeb	2,359		38.16269482	-119.9432376
Big Creek Diversion nr Fish Camp	1969-present	11267350	No	DM, PQ	NWISWeb			37.46938349	-119.6151512
Big Creek nr Wawona CA		11267400							
Budd Ck	2001-present	H01	Yes	Raw	Scripps		2593	37.87333	-119.38150
Budd Creek nr Tuolumne	1963-1973	11274730	Yes	PQ	NWISWeb	76,146		37.87353595	-119.3829353
Cherry Cr bl Dion R Holm ph, nr Mather	1963-present	11278400		DM, PQ	NWISWeb/cdec	60,606		37.89020173	-119.9699046
Cherry Cr bl Valley Dam nr Hetch Hetchy	1956-present	11277300		DM, PQ	NWISWeb/cdec	30,562		37.96769944	-119.9174029
Cherry Cr cn nr Early Intake	1956-1996	11278200		DM	NWISWeb			37.8932571	-119.9557374
Cherry Cr nr Early Intake	1956-present	11278300		DM, PQ	NWISWeb/cdec	58,534	79.0656	37.89436824	-119.9626821
Cherry Cr nr Hetch Hetchy	1910-1955	11277000		DM, PQ	NWISWeb	28,749	156.6	37.99825414	-119.9010136
Clavey R nr Long Barn	1986-1994	11283250		DM, PQ	NWISWeb	12,665	179.568	38.07658641	-120.0112948
Conness Ck (at Glen Aulin)	2001-present	H07	Yes	Raw	Scripps		2399	37.91017	-119.41867
Dana abv Gaylor	2001-present	H30	Yes	Raw	Scripps		2930	37.87917	-119.30150

Station Name	Period of Record	Station ID	In Park?	Data Type	Data Location	Drainage Area (ha)	Eleva. (m)	Lat	Long
Dana blw Gaylor	2001-present	H28	Yes	Raw	Scripps		2930	37.87917	-119.30150
Dana Ck	2001-present	H02	Yes	Raw	Scripps		2919	37.87630	-119.33250
Eleanor Cr nr Hetch Hetchy	1909-present	11278000		DM, PQ	NWISWeb/cdec	20,306	156.6	37.96908803	-119.8821241
Falls Cr nr Hetch Hetchy	1915-1983	11275000		DM, PQ	NWISWeb	11,914	186.18	37.97075376	-119.764343
Fletcher Creek	2005-present	H31	Yes	Raw	Scripps				
Gaylor Ck	2001-present	H10	Yes	Raw	Scripps		2930	37.87917	-119.30150
Hetch Hetchy Reservoir	?-present	11275500	Yes	Real-time	NWISWeb	117,850		37.94769893	-119.7879546
Illillouette Ck	2001-present	H14	Yes	Raw	Scripps		1676	37.72300	-119.55800
Illilouette Cr ne		11264000				1,566,950			
Ireland Creek	2002-present	H33	Yes	Raw	Scripps		2704	37.82569	-119.27711
Jawbone Cr nr Tuolume	1910-1911	11278500		DM	NWISWeb	4,947		37.89159079	-119.9954609
Lake Eleanor diversion tunnel	1997-present	ECK		DM, PQ	cdec		156.6	37.969	-119.881
Lake Eleanor nr Hetch Hetchy	?-present	11277500	Yes	Real-time	NWISWeb	20,230		37.9740879	-119.881013
Lewis Creek	2005-present	H60	Yes	Raw	Scripps				
Lily Cr nr Pinecrest	1964-1974	11283100		DM, PQ	NWISWeb	3,082		38.14463936	-119.9007361
Lk Eleantor Div to Cherry Lk nr Hetch Hetchy	1996-present	11277100		DM	NWISWeb		162.516	37.97964333	-119.8818464
Lower Gaylor Lake	2003-present	H35	Yes	Raw	Scripps		3155	37.91333	119.26991
Lower Granite Lake	2003-present	H38	Yes	Raw	Scripps		3066	37.90788	119.28597
Lyell abv Ireland	2002-present	H32	Yes	Raw	Scripps		2704	37.82569	-119.27711
Lyell at Maclure Bridge	2003-present	H34	Yes	Raw	Scripps		2947	37.77748	119.26213
Lyell Fk abv Merced	2001-present	H11	Yes	Raw	Scripps		2438	37.70200	-119.34700
Lyell Fork (Blw Twin Br)	2001-present	H03	Yes	Raw	Scripps		2671	37.86900	-119.33367
M Tuolumne River a Oakland Rec Camp	1916-2002	11282000		DM, PQ	NWISWeb	19,037	97.44	37.82825915	-120.0115727

Station Name	Period of Record	Station ID	In Park?	Data Type	Data Location	Drainage Area (ha)	Eleva. (m)	Lat	Long
M Tuolumne River nr Mather	1924-1933	11281500		DM, PQ	NWISWeb	13,572		37.8499241	-119.8676789
Maclure Cr bl Maclure glcr nr Toulumne Mdw	1967-1972	11274710		DM, PQ	NWISWeb	96	400.896	37.75242991	-119.2820929
Merced abv Lyell Fk	2001-present	H12	Yes	Raw	Scripps		2438	37.69700	-119.34800
Merced abv Merced Lk HSC (DC)	2001-present	H19	Yes	Raw	Scripps		2207	37.7383	-119.403
Merced at Ranger Cabin		H21	Yes	Raw	Scripps		2207	37.72949	119.39304
Merced blw Echo	2001-present	H15	Yes	Raw	Scripps		2134	37.73800	-119.44900
Merced blw Lyell Fk	2001-present	H13	Yes	Raw	Scripps		2377	37.70200	-119.34900
Merced Lk outlet	2002-present	H20	Yes	Raw	Scripps		2207	37.73814	119.41923
Merced Pk Fk Footbridge (DC)	2001-present	H18	Yes	Raw	Scripps		2486	37.69278	-119.3497
Merced R a Happy Isles Bridge nr Yosemite	1915-present	11264500	Yes	DM, PQ	NWISWeb/cdec	46,879	139.777	37.73159272	-119.5587736
Merced R a Pohono Bridge nr Yosemite	1916-present	11266500	Yes	DM, PQ	NWISWeb/cdec	83,139	134.3858	37.71687138	-119.6662788
Merced R a Yosemite	1912-1917	11265500	Yes	DM, PQ	NWISWeb	61,124		37.74381435	-119.590165
Merced R ab Illilouette		11263500	Yes			492,100			
Merced R nr Briceburg	1965-1974, 1999-present	11268200	No	DM, PQ	NWISWeb	178,969		37.63576505	-119.9332325
Middle Granite Lake	2003-present	H36	Yes	Raw	Scripps		3173	37.91749	119.27557
Parker Pass Ck	2001-present	H09	Yes	Raw	Scripps		2928	37.87820	-119.24695
Rafferty Ck	2001-present	H04	Yes	Raw	Scripps		2665	37.86667	-119.32220
Reed Cr nr Long Barn	1986-1994	11283350		DM, PQ	NWISWeb	7,045	159.21	38.00464384	-120.022128
SF Merced R a Wawona	1955-1975	11267300		DM, PQ	NWISWeb	25,900		37.53882469	-119.6621022
SF Merced R nr El Portal	1950-1975	11268000		DM, PQ	NWISWeb	62,419		37.65131973	-119.8854532
SF Merced R nr Wawona	1911-1921	11267500		DM, PQ	NWISWeb	34,188		37.54160229	-119.6732143
SF Tuolumne R at Italian F nr Sequoia	1924-1933	11279500		DM, PQ	NWISWeb	16,809		37.82325848	-119.9176806
SF Tuolumne R nr Oakland Rec Camp	1923-2002	11281000		DM, PQ	NWISWeb	22,533	97.44	37.82159266	-120.0129616

Station Name	Period of Record	Station ID	In Park?	Data Type	Data Location	Drainage Area (ha)	Eleva. (m)	Lat	Long
SF Tuolumne R nr Sequoia	1914-1917	11280000		DM, PQ	NWISWeb	17,690		37.81159223	-119.9326811
Smoky Jack Cr trib nr Yosemite Village	1963-present	11279300	Yes	PQ	NWISWeb	17,610		37.81936827	-119.7135061
South Fork Tuolumne	2002-present	H50	Yes	Raw	Scripps		2759	37.79226	119.72264
Strawberry Creek nr Wawona	1963-1973	11267700	Yes	PQ	NWISWeb	27,195		37.63604205	-119.6829422
Tenaya Cr nr Yosemite Village	1912-1958	11265000	Yes	DM, PQ	NWISWeb	12,147	139.2	37.74214772	-119.5579409
Tuolumne R (Abv Glen Aulin)	2001-present	H06	Yes	Raw	Scripps		2548	37.89950	-119.40983
Tuolumne R (Blw Glen Aulin)	2001-present	H08	Yes	Raw	Scripps		2399	37.90983	-119.42033
Tuolumne R (Hwy120 Bridge)	2001-present	H05	Yes	Raw	Scripps		2651	37.87550	-119.35450
Tuolumne R ab Early Intake nr Mather	1943-present	11276600		DM, PQ	NWISWeb/cdec	125,356		37.87936848	-119.9471261
Tuolumne R at Hetch Hetch nr Sequoia	1910-1916	11274800		DM, PQ	NWISWeb	104,636		37.9554763	-119.7593427
Tuolumne R bl early intake nr Mather	1966-2004	11276900		DM, PQ	NWISWeb/cdec	126,133		37.88159083	-119.9701824
Tuolumne R nr Hetch Hetchy	1910-2004	11276500		DM, PQ	NWISWeb/cdec	118,363	119.364	37.93742147	-119.7982326
Upper Gaylor Lake	2003-present	H37	Yes	Raw	Scripps		3155	37.92122	119.26842
Upper Granite Lake	2003-present	H39	Yes	Raw	Scripps		3181	37.93488	119.27739
Vogelsang (Fletcher Lk inlet)	2002-present	H31	Yes	Raw	Scripps		3109	37.79657	119.33913
Warren Creek	2002-present	H40	Yes	Raw	Scripps		2759	37.95251	-119.226
Yosemite Cr a Yosemite	1912-1918	11266000		DM, PQ	NWISWeb	11,059		37.74548095	-119.5954432
Yosemite Creek	2002-present	H60	Yes	Raw	Scripps		2276	37.85159	119.57496
DM= daily mean flow; DT= daily total flow; PQ= peak flow; Raw= original data as collected									
*Combined totals of river (below conduit diversion) and conduit flows									

Appendix 3: Current research projects in Sequoia and Kings Canyon National Parks

Project	Site(s)	Investigator(s)	Agency	Park Contact
Distribution of Airborne Agricultural Contaminants Relative to Amphibian Populations in the Southern Sierra Nevada	30+ lakes in the high Sierra	David Bradford	EPA	Danny Boiano
Water Chemistry of Tufa Falls	Tufa Falls Creek	Joel Despain Chris Groves	SEKI and Western Kentucky University	Joel Despain
Microbial And Hydrological Controls Of Nitrogen Losses From Alpine And Chaparral Ecosystems During Seasonal Transitions	Chamise, Emerald, Topaz and Marble Fork Kaweah	John Melack Jim Sickman	UC Santa Barbara	Annie Esperanza
Summary and publication of Tharp's and Log data	Tharp's and Log	John Melack Diana Engle	UC Santa Barbara	Annie Esperanza
Prescribed Fire Re-burn in Tharp's Watershed	Tharp's and Log	Annie Esperanza Tony Caprio	SEKI	Annie Esperanza
Effects of Landscape Scale Prescribed Fire on Hydrology and Stream Chemistry	East Fork Kaweah, Deadwood, Trauger's	Andi Heard John Stednick	Colorado State and SEKI	Tony Caprio
Western Airborne Contaminants Assessment Project	Pear and Emerald	Dixon Landers	Oregon State?, NPS, USGS	Annie Esperanza
Frogs and Pesticides in the Sierra Nevada Mountains, CA	SEKI, YOSE, Lassen	Deborah Cowman	Texas A&M University	Annie Esperanza
Sierra glacier inventory and monitoring project	SEKI,YOSE and USFS glaciers	Hassan Basagic	Portland State University	Danny Boiano
Surface Water Ambient Monitoring Program	South Fork Kings River	Pam Bufort	RWQCB	Danny Boiano
Effects of Prescribed Fire on Stream and Riparian Ecosystems in Sequoia National Park and Blodgett Forest Research Station	East Fork Kaweah tributaries	Leah Rogers Vincent Resh	UC Berkely	Tony Caprio
Hydrologic Benchmark Network	Marble Fork Kaweah	Dave Clow	USGS-WRD	Danny Boiano
Prevalence of Coliform and Other Pathogenic Bacteria in Sierra Nevada National Parks and Wilderness Area Lakes and Streams	120+ wilderness lakes and streams	Robert Derlet	UC Davis	Danny Boiano
National Park Service Monitoring of Local Drinking Water Sources and Wastewater Discharge Effluent	At least 13 drinking water sources and 7 spray fields	Paul Schwarz	SEKI	Paul Schwarz

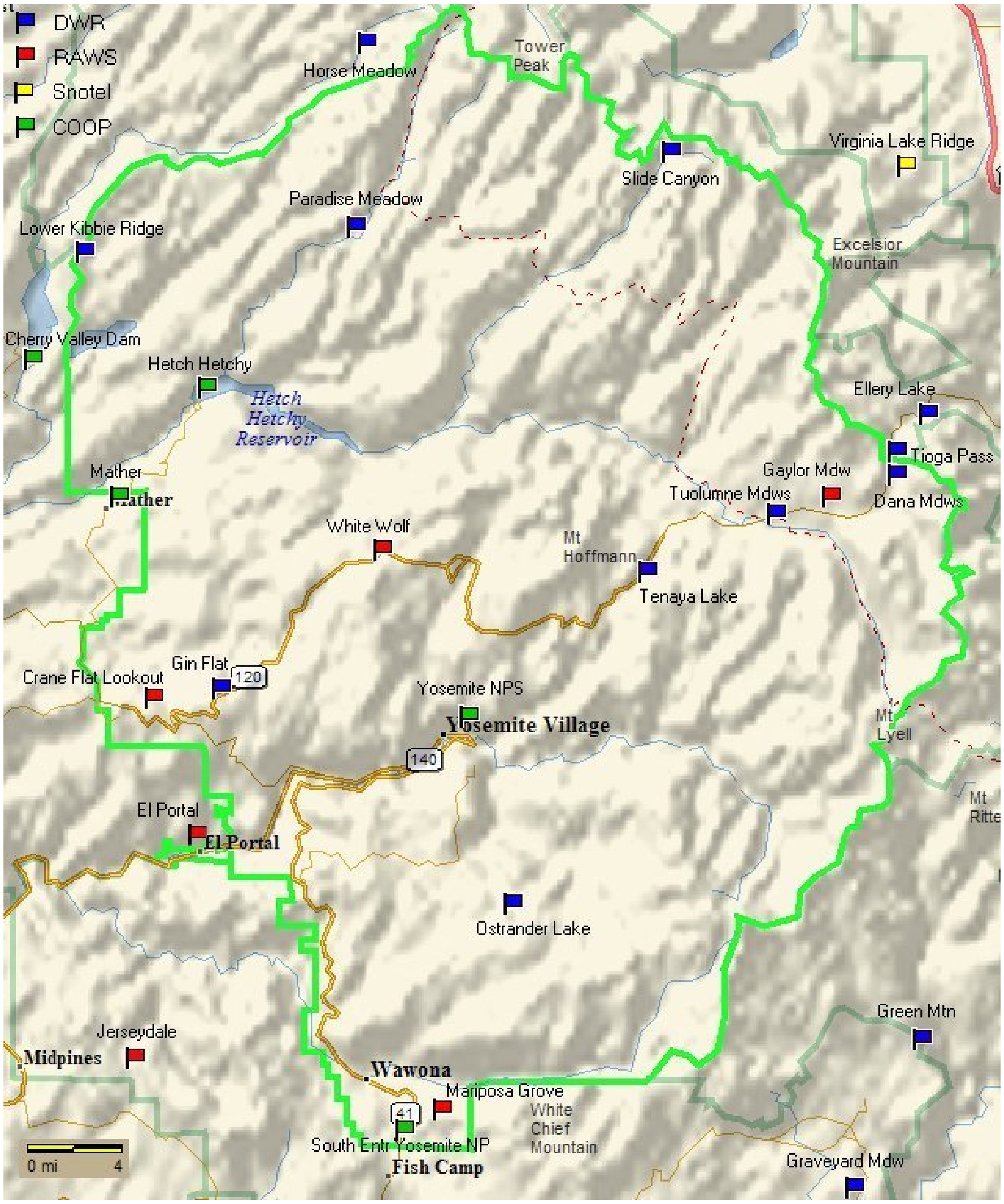
Appendix 4: Current research projects in Yosemite National Park.

Project	Site(s)	Principle Investigator(s)	Agency	Park Contact
Hydroclimate Monitoring Network	Upper Merced and Tuolumne	Dan Cayan Mike Dettinger	USGS and Scripps	Joe Meyer
Nitrogen Deposition and Risk Assessment	Upper Merced and Tuolumne	Dave Clow	USGS	Lee Tarnay
Hydrological and ecological effects of groundwater pumping on water levels, fen carbon budget, and vegetation in Doghouse Meadow	Doghouse Meadows	David Cooper	Colorado State	Jim Roche
Frogs and Pesticides in the Sierra Nevada Mountains, CA	SEKI, YOSE, Lassen	Deborah Cowman	Texas A&M University	
Sierra glacier inventory and monitoring project	SEKI,YOSE and USFS glaciers	Hassan Basagic	Portland State University	Joe Meyer
Prevalence of Coliform and Other Pathogenic Bacteria in Sierra Nevada National Parks and Wilderness Area Lakes and Streams	120+ wilderness lakes and streams	Robert Derlet	UC Davis	Joe Meyer

Appendix 5: Current meteorology, air quality and snow pack monitoring sites in Devils Postpile National Monument (DEPO) and Sequoia and Kings Canyon National Parks (SEKI).

Park	Site Location	Program	Available Data	Beg.Record
			METEOROLOGY	
DEPO	Ranger Station	NPS RAWS	weather and fuel sticks	1994
SEKI	Lookout Point	NPS/ CASTNet	hourly met station	1997
	Emerald Lake	EOS/ UCSB	hourly met station	1984
	Topaz Lake	EOS/ UCSB	hourly met station	1996
	Atwell Mill	Army Corps. Eng.	daily precip totals	1975
	Ash Mountain	NPS/ NOAA	temp and precip	1928
	Giant Forest	NPS/ NOAA	temp and precip	1928
	Lodgepole	NPS/ NOAA	temp and precip	1928
	Grant Gorve	NPS/ NOAA	temp and precip	1928
	Cedar Grove	NPS RAWS	weather and fuel sticks	1992
	Sugar Loaf	NPS RAWS	weather and fuel sticks	1993
	Rattlesnake	NPS RAWS	weather and fuel sticks	1994
	Wolverton helispot	NPS RAWS	weather and fuel sticks	1995
	Ash Mountain	NPS Air	hourly met station	
	Lower Kaweah	NPS Air	hourly met station	
			AIR QUALITY	
SEKI	Lower Kaweah	NADP	precipitation chemistry	1980
	Lower Kaweah	NPS	visibility w/ repeat photography	1983
	Lookout Point	CASTNet	dry deposition	1997
	Ash Mountain	IMPROVE	fine particulate matter	1992
	Ash Mountain	PRIMENet	UV	1998
			SNOW	
SEKI	29 sites throughout SEKI	CA Water Resources	depth and SWE (some include precip)	

Appendix 6: Current meteorology stations in Yosemite National Park.



Appendix 7: Beneficial uses for the State of California with associated codes and descriptions (Information Center for the Environment 2003).

Code	Beneficial Use Name	Beneficial Use Description
AGR	Agricultural Supply	Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.
ALL	All Beneficial Uses	All beneficial uses
AQUA	Aquaculture	Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.
BIOL	Preservation of Biological Habitats	Uses of water that support designated areas or habitats, such as Areas of Special Biological Significance (ASBS), established refuges, parks sanctuaries, ecological reserves, or other areas where the preservation or enhancement of natural resources required special protection.
COLD	Cold Freshwater Habitat	Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
COMM	Commercial and Sport Fishing	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.
EST	Estuarine Habitat	Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish shellfish, or wildlife (e.g, estuarine mammals. waterfowl, shorebirds).
FLD	Flooding	Beneficial uses of riparian wetlands in flood plain areas and other wetlands that receive natural surface drainage and buffer its passage to receiving waters.
FRSH	Freshwater Replenishment	Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.
GWR	Ground Water Recharge	Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting salt water intrusion into fresh water aquifers.
IND	Industrial Service Supply	Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.

Code	Beneficial Use Name	Beneficial Use Description
MAR	Marine Habitat	Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shore birds).
MIGR	Migration of Aquatic Organisms	Uses of water that support habitats necessary for migration, acclimatization between fresh and salt water, or other temporary activities by aquatic organisms, such as anadromous fish.
MUN	Municipal and Domestic Supply	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
NAV	Navigation	Uses of water for shipping, travel, or other transportation by private, military, or commercial Vessels.
NONE		No designated beneficial uses
POW	Hydropower Generation	Uses of water for hydropower generation.
PROC	Industrial Process Supply	Uses of water for industrial activities that depend primarily on water quality.
RARE	Rare, Threatened or Endangered Species	Preservation of Rare, Threatened, or Endangered Species.
REC1	Water Contact Recreation	Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.
REC2	Non-Contact Water Recreation	Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing.
SAL	Inland Saline Water Habitat	Uses of water that support inland saline water ecosystems including, but not limited to, preservation or enhancement of aquatic saline habitats, vegetation, fish or wildlife, including invertebrates.
SHELL	Shellfish Harvesting	Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.
SPWN	Spawning, Reproduction, and/or Early Development	Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Code	Beneficial Use Name	Beneficial Use Description
WARM	Warm Freshwater Habitat	Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
WET	Wetland Habitat	Uses of water that support wetland ecosystems, including, but not limited to, preservation or enhancement of wetland habitats, vegetation, fish shellfish, or wildlife, and other unique wetland functions which enhance water quality, such as providing flood and erosion control, stream bank stabilization, and filtration and purification of naturally occurring contaminants.
WILD	Wildlife Habitat	Uses of water that support terrestrial ecosystems including, but not limited to, the preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources
WQE	Environmental Water Quality	Beneficial uses of waters that support natural enhancement or improvement of water quality in or downstream of a water body including, but not limited to, erosion control filtration and purification of naturally occurring water pollutants, streambank stabilization, maintenance of channel integrity, and siltation control.

Appendix 8: Beneficial uses for stream segments in Devils Postpile National Monument (DEPO) and Sequoia and Kings Canyon National Parks (SEKI) (California Regional Water Quality Control Board Central Valley Region 1995). Beneficial use codes and descriptions are listed in Appendix 7**.**

			Beneficial Uses													
Park	**Watershed**	**Stream Segment**	**MUN**	**AGR**	**IND**	**PROC**	**POW**	**REC1**	**REC2**	**WARM**	**COLD**	**WILD**	**RARE**	**SPWN**	**GWR**	**FRSH**
DEPO	San Joaquin	Sources to Millerton Lake	X	X			X	X	X	X	X	X				
SEKI	San Joaquin	Sources to Millerton Lake	X	X			X	X	X	X	X	X				
	Kings	Main Fork, Above Kirch Flat	X					X	X	X	X	X	X	X		X
	Kaweah	Above Lake Kaweah	X				X	X	X	X	X	X	X	X		X
	Tule	Above Lake Success	X	X			X	X	X	X	X	X	X	X		X
	Kern	Above Lake Isabella	X				X	X	X	X	X	X	X	X		X
YOSE	Merced	Source to McClure Lake		X			X	X	X	X	X	X				
	Tuolumne	Source to (new) Don Pedro	X	X			X	X	X	X	X	X				